PN-ACH-829

IFPRI

RESEARCH REPORT 106

Wheat Production in Bangladesh

Technological, Economic, and Policy Issues

Michael L. Morris
Nuimuddin Chowdhury
Craig Meisner

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute was established in 1975 to identify and analyze alternative national and international strategies and policies for meeting food needs of the developing world on a sustainable basis, with particular emphasis on low-income countries and on the poorer groups in those countries. While the research effort is geared to the precise objective of contributing to the reduction of hunger and malnutrition, the factors involved are many and wide-ranging, requiring analysis of underlying processes and extending beyond a narrowly defined food sector. The Institute's research program reflects worldwide collaboration with governments and private and public institutions interested in increasing food production and improving the equity of its distribution. Research results are disseminated to policymakers, opinion formers, administrators, policy analysts, researchers, and others concerned with national and international food and agricultural policy.

IFPRI is a member of the Consultative Group on International Agricultural Research and receives support from the Arab Fund for Economic and Social Development, Argentina, the Asian Development Bank, Australia, Belgium, Canada, China, Denmark, the European Commission, the Ford Foundation, France, the German Agency for Technical Cooperation (GTZ), the German Federal Ministry for Economic Cooperation and Development (BMZ), India, the Inter-American Development Bank, the International Development Research Centre (Canada), the International Fund for Agricultural Development, Ireland, Japan, the Land and Agriculture Policy Centre (South Africa), Mozambique, the Netherlands, Norway, the Philippines, the Rockefeller Foundation, the Rural Industries Research and Development Corporation (Australia), South Africa, the Southern African Development Bank, Spain, Sweden, Switzerland, the United Kingdom, the United Nations Children's Fund, the United States, and the World Bank.

Wheat Production in Bangladesh

Technological, Economic, and Policy Issues

Michael L. Morris

Nuimuddin Chowdhury

Craig Meisner

International Food Policy Research Institute
Washington, D.C.

Library of Congress Cataloging-in-Publication Data

Morris, Michael L.
Wheat production in Bangladesh: technological, economic, and policy issues / by Michael L. Morris, Nuimuddin Chowdhury, and Craig Meisner.
p. cm. — (Research report ; 106)
Includes bibliographic references.
ISBN 0-89629-109-X
1. Wheat trade—Bangladesh. 2. Wheat trade—Government policy—Bangladesh. I. Chowdhury, Nuimuddin, 1948– . II. Meisner, Craig. III. Title. IV. Series: Research report (International Food Policy Research Institute); 106.

HD9049.W5B315 1997
338. 1'7311'095492—dc21 97-36834

Contents

Tables

Figures

Foreword

In the early 1990s, a World Bank study concluded that wheat yields were so low and wheat was so unprofitable, compared with *boro* rice, that there was no good reason to encourage the expansion of wheat production in Bangladesh.

By 1994, however, the situation had changed. As Bangladesh neared self-sufficiency in rice, its profitability was declining. By then, the demand for wheat was increasing faster than the demand for rice, and imports of wheat were growing. Perhaps it was time for the government to rethink its policies on wheat production. As part of its extensive food policy research project in Bangladesh, IFPRI, in collaboration with the International Maize and Wheat Improvement Center (CIMMYT), the Wheat Research Center in Dinajpur, and several other national institutions, agreed to conduct a new study to determine what stance policymakers should take regarding wheat.

Although this research also found that *boro* rice has a decided comparative advantage over wheat overall, it uncovered a number of areas where conditions for wheat-growing are superior to rice. In these areas wheat is highly competitive and deserves to be supported, particularly by policies that encourage technological improvements in wheat production.

These results from Bangladesh have wider applications in that many countries attempting to intensify their agricultural production experience rapid growth in one crop but not in others. As this report by Michael Morris, Nuimuddin Chowdhury, and Craig Meisner indicates, careful attention to seasonal and local differences can lead to policies that encourage productivity growth in secondary crops.

Finally, in addition to IFPRI and CIMMYT, the work was funded by the Canadian International Development Association, the U. S. Agency for International Development, and the Australian Agency for International Development. We are grateful for their support.

Per Pinstrup-Andersen
Director General

Acknowledgments

Although it is not possible to name all those who contributed to this report, a number of people deserve particular mention. We are pleased to acknowledge a special debt to Steve Haggblade, chief of party of the Bangladesh Food Policy Project of the International Food Policy Research Institute (IFPRI), without whose unflagging support the study could not have been completed.

Terms of reference were originally set forth by an advisory committee that included Ron Dalgleish and Evelyn Lee of the Canadian International Development Association (CIDA), Sufi Ahmed of the International Maize and Wheat Improvement Center (CIMMYT), Raisuddin Ahmed and Steve Haggblade (IFPRI), and Shirley Pryor of the U.S. Agency for International Development (USAID). R. A. Fischer and Derek Byerlee (CIMMYT) provided valuable input during the design phase, and Akhter Ahmed (IFPRI) contributed useful feedback on the survey instruments. Mahbub Morshed ably managed the wheat producer survey, assisted by the supervisor of enumerators, Ashequl Islam. The interviews were conducted by A. B. M. Khairul Anam, Shamshul Arefin, A. S. Mollah, Mizanur Rahman, M. Zakaria, and M. Taslim. Analysis of the survey data was carried out by Mahfuzul Kabir, Kibria Masud Khan, and Rahina Kaneez. M. A. Razzaque of the Wheat Research Centre in Dinajpur, Bangladesh, shared his considerable knowledge of the wheat sector, as did many of his staff. M. Akhtaruzzaman of the U.S. Department of Agriculture met with us for a number of informative discussions. Early drafts of the report were read by R. A. Fischer, Steve Haggblade, David Atwood (USAID), and Raisuddin Ahmed (IFPRI). Steven Vosti and Sherman Robinson served as IFPRI reviewers. Manohar Sharma, Shenggen Fan, and Towa Tachibana (IFPRI) contributed useful comments, as did two anonymous external reviewers. Last but not least, we would like to express our heartfelt gratitude to Hans Lofgren of IFPRI, who meticulously reviewed several drafts of the manuscript and made numerous suggestions that greatly strengthened the final product.

Funding for the study was provided by CIDA, CIMMYT, IFPRI, USAID, and the Australian Agency for International Development.

Summary

This report presents the findings of a study undertaken to assess the economics of wheat production in Bangladesh. Following recent gains in rice production, which made the prospect of achieving national self-sufficiency in cereals a distinct possibility, many government policymakers and donor agency representatives decided that the case for promoting domestic wheat production warranted careful reexamination. They considered another study necessary because of lingering questions about the findings of two previous studies, which concluded that wheat production is not only unprofitable for most farmers, but also represents an inefficient use of the nation's resources. These earlier findings are difficult to reconcile with the fact that more than 2 million households in Bangladesh continue to grow wheat.

This study examines wheat production in different regions of Bangladesh using a combination of financial and economic analysis. As a basis for this study, plot-level data, including data on land elevation and soil characteristics, were collected from 421 farms distributed throughout Bangladesh's wheat-growing areas in an effort to identify the factors that motivate farmers' planting decisions and influence the relative profitability of wheat versus alternative crops. The survey data were used to develop budgets for two irrigated crops (wheat and *boro* rice) and three nonirrigated crops (wheat, oilseeds, and pulses) grown during the *rabi* season. For each crop, separate budget sets were developed in each of five wheat production zones, distinguished according to location, land elevation, soil texture, and other factors. The financial and economic profitability of competing production activities were compared in each of the five zones to determine the degree to which government policies and market failures may have caused financial profitability to diverge from economic profitability. Zonal rankings of relative production efficiency, based on domestic resource cost (DRC) ratios and other cost-benefit measures, were generated to assist in determining the prevailing pattern of comparative advantage.

The results presented in this report support one important finding of the earlier studies: *boro* rice frequently generates greater financial net returns to farmers' labor and management and to land than other *rabi* crops. Although the financial profitability of *boro* rice production has declined now that Bangladesh is nearing self-sufficiency in rice and domestic market prices for rice have fallen, *boro* rice remains the most profitable option in areas where *boro* rice production is technically feasible. One reason that

boro rice is relatively more profitable than wheat in financial terms is that farmers' incentives to plant wheat are being undermined by the government's policy of accepting large quantities of low-cost wheat food aid, which serves to depress domestic wheat prices.

In addition to supporting this major finding of the earlier studies, this study has generated important new information:

- In many regions of Bangladesh, wheat is an attractive crop. Although *boro* rice tends to be more profitable in financial terms, *boro* rice cannot be grown everywhere. Differences in land elevation and soil texture matter. Soil data and other data taken at the plot level indicate that farmers plant *boro* rice predominantly in heavy soils located in low-lying areas well-served by irrigation infrastructure. *Boro* rice is rarely grown in lighter soils located in more elevated areas, and it is never grown where reliable irrigation services are absent. These latter conditions are present in the northwestern, north central, south central, and southwestern regions of the country, precisely where most wheat production presently is concentrated. In areas unsuited for *boro* rice, wheat is often highly competitive.
- Wheat production can represent an efficient use of domestic resources. When production inputs and outputs are assigned economic prices representing their scarcity value, the relative profitability of wheat increases considerably. Under economic pricing, wheat currently dominates the efficiency rankings in most nonirrigated areas, and it is competitive with *boro* rice in a number of irrigated areas. Should Bangladesh become a consistent rice exporter, the economic case for wheat could become even stronger.
- For many rural households, the decision to grow wheat is influenced by the desire to avoid seasonal food shortages. Two-fifths of the survey respondents indicated that their primary reason for growing wheat is to ensure adequate household food supplies during the "hungry season" prior to the *boro* rice harvest.

These results help explain why so many rural households persist in growing wheat despite pronouncements by influential analysts that the crop is unprofitable. Contrary to conventional wisdom, wheat often represents a profitable production alternative. The crop budgets, disaggregated by production zone and by irrigation status to more accurately reflect the choices facing Bangladeshi farmers, indicate that although wheat rarely will be able to compete with *boro* rice in areas where agroclimatic factors favor *boro* rice, wheat represents an attractive option in areas where *boro* rice cannot be grown.

These findings have important implications for policy. They suggest that support to wheat should not be reduced on the grounds that wheat production represents an inefficient use of the nation's resources. While the desirability of investing in wheat research and wheat promotion activities should be evaluated carefully (as should the desirability of providing support to other crops), the fact that wheat production is presently efficient in some zones and is likely to become efficient in additional zones in the future suggests that attractive investment opportunities can be identified and exploited.

Reforming the policies that currently discriminate against wheat would lead to greater wheat production. At present, domestic wheat prices are below import parity levels, eroding the profitability of wheat production. An accumulating body of evidence suggests that low domestic wheat prices can be attributed in large part to influxes of wheat food aid and to subsidized commercial imports of wheat. Although food aid and commercial subsidies are paid for by foreign governments and do not represent a direct cost to Bangladesh, it would be better if development assistance could be received without causing major domestic price distortions. Changes in food aid policies, including the substitution of other commodities for wheat or the monetization of food aid, would help to raise wheat prices, thus strengthening incentives for domestic wheat producers and reducing the nation's dependence on food imports.

In addition, agricultural research and extension priorities may need to be reevaluated. Although a detailed evaluation of research investment opportunities was beyond the scope of this study, the fact that the yield gap for wheat remains much larger than for other leading cereals suggests that the expected returns to increased investment in wheat research may be considerable. Based on current patterns of economic profitability, attractive opportunities for investment in wheat research are likely to be concentrated in rainfed areas unsuited for *boro* rice production.

Finally, these results from Bangladesh have important implications for other countries that are seeking to maintain productivity growth in the face of agricultural intensification. Many developing countries resemble Bangladesh in having experienced an uneven pattern of productivity growth during the post-Green Revolution period. In Bangladesh, the dramatic productivity gains in rice have not been matched in other important cereals. Maintaining productivity growth across the entire agricultural sector will depend on increasing productivity among secondary crops and "niche" commodities that exploit specific locational and seasonal advantages. Economic analyses conducted at a high level of aggregation will often miss these potential sources of growth. This study of wheat in Bangladesh illustrates how seasonal and locational details matter, and it shows how policy analysis carried out at an appropriate level of disaggregation can help in identifying efficient production activities.

CHAPTER 1

Background of the Study

With more than 110 million inhabitants concentrated on 144,000 square kilometers, Bangladesh is one of the most densely populated countries on earth. Faced with the challenge of having to support nearly 800 persons per square kilometer from a natural resource base that is already severely overtaxed, successive governments have promoted industrialization in an attempt to diversify the economy away from its traditional reliance on agriculture. Despite these efforts, industrial growth has remained sluggish, leaving agriculture as the mainstay of the economy. Agricultural activities account for more than one-third of gross domestic product (GDP) and employ nearly two-thirds of the labor force (World Bank 1995).

Trends in Bangladesh's Agricultural Sector

During the past 25 years, the agricultural sector of Bangladesh has experienced a great deal of turbulence. Immediately after the achievement of independence in 1971, a series of disastrous harvests (attributable in large part to unfavorable weather) led to widespread food shortages, forcing the government to issue urgent appeals to the international community for emergency relief assistance. Massive imports of cereals, edible oils, and dairy products became a regular feature of the economy, and Bangladesh developed a reputation as one of the world's most impoverished nations. Following the return of more normal weather in the late 1970s, the agricultural sector recovered, and a succession of satisfactory harvests helped to replenish the nation's grain stocks. However, the recovery turned out to be temporary. Since population growth continued to outpace growth in food production, regular imports of cereals became necessary to meet chronic shortfalls.

Concerned about the widening structural gap between food supply and demand, in 1980 the government launched an ambitious plan to increase production of cereals, with particular emphasis on the two primary staples, rice and wheat. Key components of this plan (as spelled out in the Second Five-Year Plan) included heavy investment in infrastructure for flood control, drainage, and irrigation; expansion of targeted production credit; subsidized distribution of seed of high-yielding modern varieties of rice and wheat;[1] and increased funding of agricultural research. In addition to these actions taken to increase the direct role of government in promoting food production, policy reforms were implemented to improve the efficiency of private markets for inputs. After a series of false starts, irrigation policy was liberalized, and responsibility for procurement and distribution of fertilizer was gradually ceded to the private sector.

In time these actions had a noticeable impact. Starting in the late 1980s, rice production began to accelerate, and by the end of the decade the nation was approaching self-sufficiency in rice. Wheat production also increased sharply, and the proportion of wheat that had to be imported declined significantly. Poor harvests in 1995 and 1996 reversed some of the progress that had been achieved, but all signs indicate that these weather-related setbacks will prove temporary.

Policy Issues Facing the Government

Although the impressive cereal production gains constitute welcome news, the fact that Bangladesh now stands at the threshold of self-sufficiency in rice threatens to raise new and unfamiliar challenges for policymakers. Assuming that longer-term production trends resume, the government soon may have to confront the problem of how to dispose of rice surpluses. The problem is considerably complicated by the policies for rice that cannot be formulated independently of policies for other cereals that can substitute for rice in either production or consumption. Nowhere are these linkages more evident than in the case of wheat. Because wheat competes with rice both in farmers' fields and on consumers' tables, policies affecting rice are inextricably linked to policies affecting wheat. Some analysts, noting the high yields of *boro* rice (which is grown during the cool, dry *rabi* season when wheat is also grown), have concluded that wheat production represents a relatively inefficient use of resources and have argued that efforts to promote wheat production should be scaled back to allow greater emphasis to be placed on *boro* rice (World Bank 1992; Abdul Aziz 1993). This argument is reinforced by the perception that wheat, a relatively new crop in Bangladesh, is not well adapted to local agroclimatic conditions. Although not always backed by rigorous analysis, such arguments have proved persuasive in the national policy debate.

Objectives of the Study

This report presents the findings of a study designed to assess the economics of wheat production in Bangladesh. Faced with the prospect of achieving national self-sufficiency in rice, government policymakers (as well as the international donors who provide support to Bangladesh) have questioned whether wheat production should be aggressively promoted in the future. Their concern is understandable: with foodgrain imports expected to decline as the nation approaches self-sufficiency in cereals, an im-

[1] Many of these modern varieties of rice and wheat were developed from improved germplasm provided by the International Rice Research Institute (IRRI) and the International Maize and Wheat Improvement Center (CIMMYT).

portant question for policymakers is whether wheat imports (including food aid) can be replaced by efficient domestic production. Given the scarcity of resources available for agricultural research and development, it would be difficult to justify continued investment in a crop whose production represents a wasteful use of resources.

Some specific objectives of the study were

- to conduct a national survey of wheat producers in order to generate reliable data on farmers' practices for use in identifying major wheat-based cropping systems;
- to develop financial and economic budgets for wheat and major competing crops in order to establish the profitability of growing wheat from the point of view of farmers and of the nation;
- to analyze the sources of differences between financial and economic profitability in order to determine the effect on production incentives of policy-induced distortions;
- to explore how changes in key parameters such as production technologies, government policies, and international prices of key inputs and outputs are likely to affect the economics of wheat production over the longer term; and
- to spell out implications of these results for policymakers.

Literature Review

During the early 1990s, the World Bank conducted a major review of food policy in Bangladesh (World Bank 1992). The review examined the profitability of important food and fiber crops, calculated the level of protection (positive or negative) afforded by government policies, and drew a number of conclusions about the pattern of comparative advantage prevailing in several regions of the country. Although the review focused mainly on rice, three wheat production systems were included in the analysis. The World Bank team drew two general conclusions regarding wheat: (1) in financial terms, wheat production is not profitable, and (2) if prices are adjusted to eliminate the distortionary effects of government policies, wheat production does not represent an efficient use of domestic resources. Based on these findings, the World Bank team expressed pessimism about the future prospects for wheat production in Bangladesh.

While the World Bank study was under way, researchers from the Bangladesh Institute of Development Studies (BIDS) and the International Food Policy Research Institute (IFPRI) were collaborating on a series of studies that focused on the financial and economic profitability of alternative crops in Bangladesh (see Mahmud, Rahman, and Zohir 1994). Like the World Bank team, the BIDS-IFPRI researchers focused primarily on rice production systems, although they also considered a number of nonrice crops. Based on their analysis, the BIDS-IFPRI researchers reached similar conclusions regarding wheat: (1) in financial terms, wheat production is not profitable, and (2) after adjusting prices to eliminate the distortionary effects of government policies, wheat production still is not profitable. The BIDS-IFPRI researchers noted that rainfed wheat production is slightly less unprofitable than irrigated wheat production, but they concluded that wheat production is unlikely to become profitable unless unanticipated technological breakthroughs occur in the development of heat-resistant varieties.

Given the data on which they were based, and considering the prices that prevailed at the time the studies were carried out, the main conclusions of the World Bank and the BIDS-IFPRI studies are unobjectionable. However, the findings can be questioned today on at least two grounds.

First, in both studies the crop budgets used to assess the profitability of wheat versus alternative crops were developed using data whose quality or relevance must be questioned. The World Bank team estimated input-output parameters on the basis of small-sample secondary data whose reliability was never thoroughly verified at the field level.[2] The BIDS-IFPRI team conducted a number of field surveys, but as in the World Bank study, data from different wheat-growing regions were subsequently combined. In the end, both studies calculated nationwide efficiency measures for a small number of stylized wheat production technologies, glossing over potentially important variability between regions and production environments.

Second, both studies were conducted at a time when Bangladesh was importing rice to make up perennial domestic production shortfalls. In calculating the economic profitability of rice versus alternative crops, the World Bank and BIDS-IFPRI teams therefore correctly assigned each marginal unit of domestically produced rice an economic value equal to the import parity price. However, that Bangladesh is nearing self-sufficiency in rice represents an important change. In years of favorable weather, domestically produced rice no longer substitutes for imports, so its economic value at the margin is determined by domestic supply and demand forces at a level well below the import parity price. Should long-term production trends resume, Bangladesh could easily find itself with a net rice surplus, which will be exportable only at an even lower price, the export parity price. These developments have reduced the profitability of rice production, and they may have altered the efficiency rankings that prevailed when Bangladesh was a consistent rice importer.

[2] J. Metzel, World Bank, personal communication, June 1994.

CHAPTER 2

Methodology and Data Sources

This study[3] examines wheat production in Bangladesh using a combination of financial and economic analysis designed to answer the following question: under what circumstances does wheat production represent a relatively efficient use of Bangladesh's domestic resources (land, labor, and capital), ignoring the effect of distortions in the economy resulting from government policies and market failures? Relative efficiency in production depends on three factors: (1) *technology* (which determines production possibilities and influences rates of product transformation), (2) *resource endowments* (which affect the value of domestic resources, such as land, labor, water, and capital), and (3) *international prices* (which directly determine the value of tradable inputs and outputs and indirectly influence the value of domestic resources).

Methodology

The analysis is based on the following steps:

1. Five major wheat production zones are identified. These five zones, which differ in their suitability for wheat production, are defined in terms of geographical location, taking into account technical factors such as land elevation and soil type.
2. For each of the five zones, budgets are developed for wheat and alternative crops cultivated during the winter (*rabi*) season. Input-output parameters for the crop budgets are estimated from plot-level data collected by means of a national survey of wheat producers.
3. Production inputs and outputs are assigned two sets of prices: *financial prices* and *economic prices*. Financial prices are the actual market prices paid or received by farmers, inclusive of taxes, subsidies, and other transfers. Economic prices are shadow prices that have been adjusted to account for the effects of government policies, market failures, and other distortions.

[3] This study was conducted by CIMMYT and IFPRI researchers, working in collaboration in Bangladesh.

4. The crop production budgets and the two price vectors are used to calculate the financial and economic profitability of wheat versus alternative crops. Differences between financial and social profitability are then disaggregated to determine the direction and size of the distortions attributable to government policies or market failures or both.
5. Information from the profitability analysis is used to calculate domestic resource cost (DRC) ratios. DRCs are measures of production efficiency that help policymakers to identify patterns of comparative advantage.
6. Analysis is carried out to test the sensitivity of the current profitability rankings to changes in the values of key parameters whose future behavior is difficult to predict with precision. Sensitivity analysis is considered essential because policy decisions made on the basis of comparative advantage generally have long-term implications. Thus it is important to distinguish between dimensions of the current situation that can be expected to prevail over the longer run and dimensions that could change as the result of technical or economic developments.

Limitations of the Analytical Framework

The approach used for this study provides a convenient framework for assessing current patterns of comparative advantage among a set of competing crops by quantifying the economic cost of keeping resources in their production. However, it is important to note several inherent limitations of the methodology.

First, the use of crop production budgets to determine the relative efficiency of a set of cropping activities carried out within a single cropping season represents a partial-equilibrium approach and consequently fails to capture possible linkages between the immediate cropping activities under consideration and other parts of the agricultural and nonagricultural economies. Adequately accounting for all of these linkages is beyond the scope of the study and would require the use of one or more detailed models covering the entire agricultural sector (including household-level decisionmaking), as well as interactions between the agricultural and nonagricultural sectors, and with the macroeconomy.[4]

Second, no attempt is made to incorporate risk factors into the analysis. The crop production budgets are developed using average input-output parameters, without explicitly taking into account cross-sectional and temporal variability in key parameters, as well as other factors that are known to influence household-level production and consumption decisions.

Third and arguably most important, the use of DRC results as a basis for making long-term policy decisions presents a number of conceptual problems. Although efficiency rankings based on DRCs are commonly interpreted as providing an empirical measure of comparative advantage, the relationship between DRCs and comparative advantage is at best indirect. Since the efficiency rankings generated by DRC analysis

[4] Sensitivity analysis is used to address several shortcomings associated with the partial-equilibrium nature of the analytical framework; these could have been addressed endogenously had a more sophisticated framework been used.

are specific to a set of conditions that are bound to change, DRCs may lack sufficient information to guide decisions for long-term production and investment.[5]

Data Sources

Data used for defining wheat production zones and for constructing crop budgets were collected in early 1993 through a survey of 421 farm households located throughout wheat-growing areas of Bangladesh. A four-stage, clustered, stratified sampling procedure was used to ensure that growers of the five principal *rabi* crops (irrigated rice, irrigated wheat, rainfed oilseeds, rainfed pulses, and rainfed wheat) would be represented in the sample in sufficiently large numbers to permit estimation of crop budgets for each production alternative. (For a description of the survey, see Appendix 1.)

[5] For discussion of the relationship between DRCs and comparative advantage, see Scandizzo and Bruce 1980; Monke and Pearson 1989; Tsakok 1990; and Mahmud, Rahman, and Zohir 1994.

CHAPTER 3

Wheat in the Agricultural Economy of Bangladesh

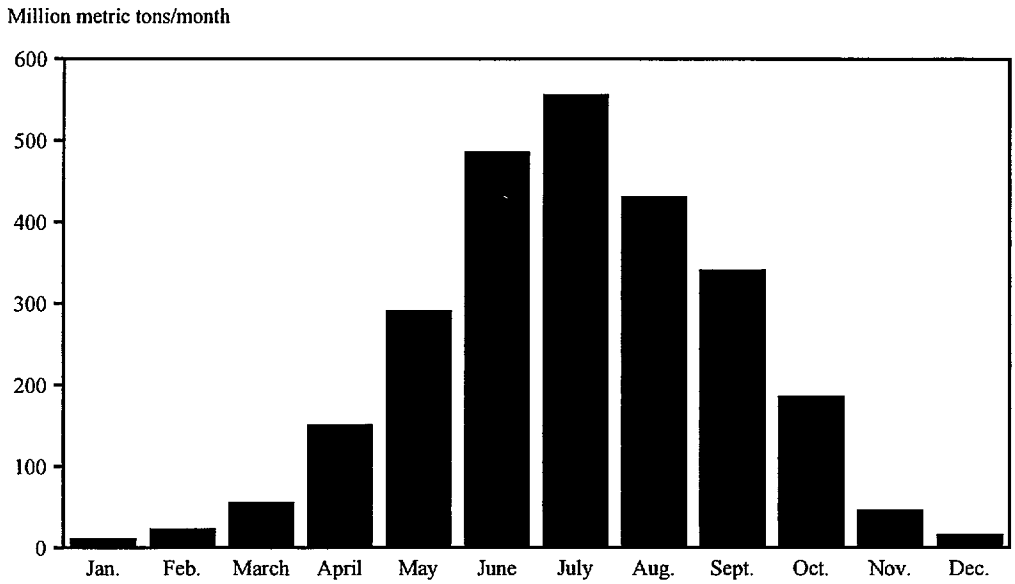
Bangladesh extends across a delta formed by the confluence of three major river systems. Approximately 88 percent of the country's land surface consists of low-lying floodplains made up of alluvial soils that are subject to periodic flooding. The remaining 12 percent of the land surface (located in the far southeast) consists of hill tracts. Although there is no universally accepted system of land classification, land types generally are distinguished according to their susceptibility to seasonal flooding. Within the northern and central floodplains, roughly one-quarter of the area is classified as low-lying or extremely low-lying; this land is subject to prolonged periods of deep annual flooding. The remaining three-quarters of the area (not including the hill tracts) are classified as highlands or medium highlands; this land is subject to brief periods of shallow flooding.

Bangladesh has a subtropical climate featuring one rainy season (monsoon) (Figure 1). About 80 percent of annual rainfall occurs during the hot summer season (*kharif*), which lasts from April to October and is characterized by overcast skies, high temperatures, and low solar radiation. The remaining 20 percent of annual rainfall is distributed unevenly throughout the cool winter season (*rabi*), which lasts from November through March and is characterized by clear skies, lower temperatures, and high evapotranspiration rates. Annual rainfall varies from 1,200 to 3,500 millimeters, generally increasing as one moves from the northwest toward the southeast. Temperatures also are unimodally distributed, with the hottest temperatures generally occurring during the months of highest rainfall (Figure 2).[6]

Soils are distinguished according to texture, nutrient status, and organic content. Soils range from lighter-textured sandy loam (concentrated in highland and medium highland areas) to heavier-textured clay-loam and silts (concentrated in low-lying and

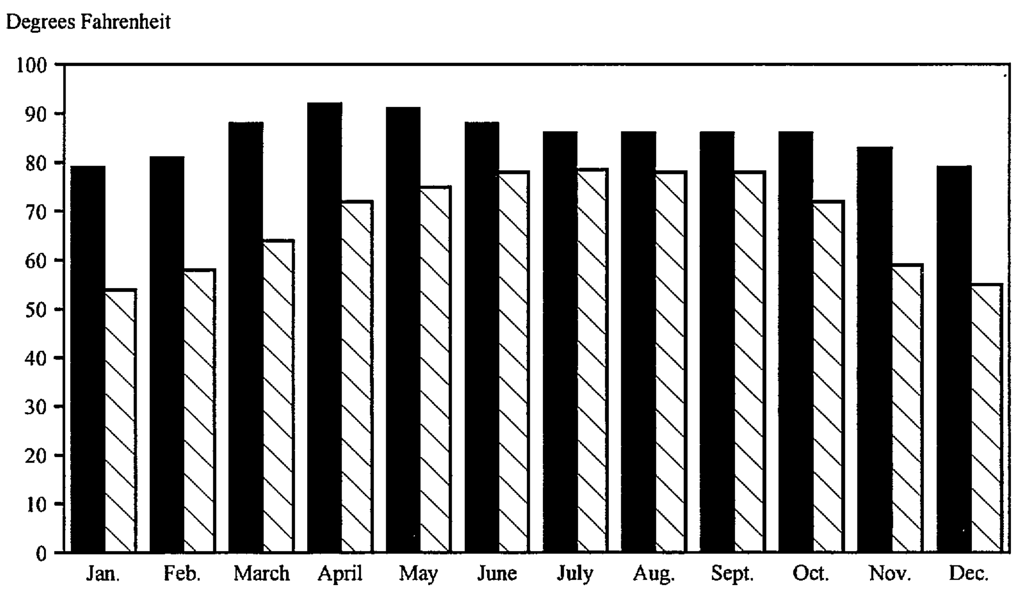
[6] The unimodal distribution of mean monthly temperatures is more pronounced for nighttime temperatures (minima); during months of peak rainfall (June to August), daytime temperatures (maxima) are frequently affected by cloud cover.

Figure 1—Distribution of monthly rainfall



Source: Bangladesh Meteorological Department.

Figure 2—Mean monthly maximum and minimum temperatures



Source: Bangladesh Meteorological Department.

extremely low-lying areas). The organic content of most soils is very low (averaging less than 1 percent), reflecting a long history of continuous, extensive cultivation.

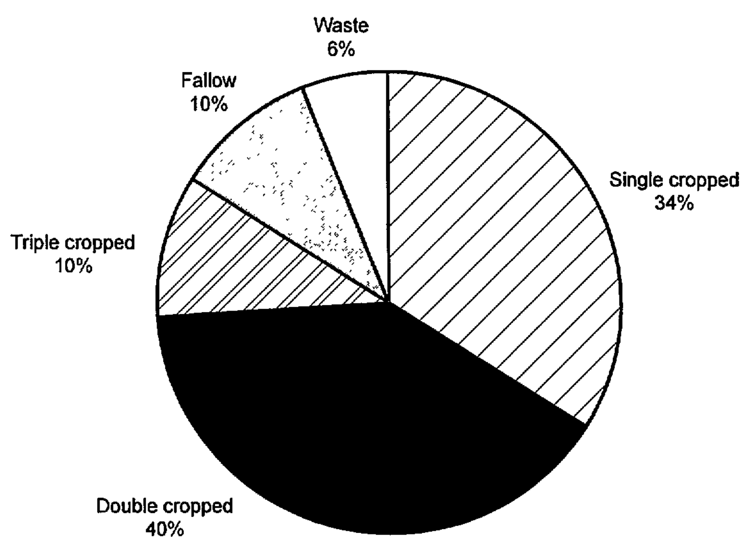
Principal Crops and Cropping Patterns

Rapid population growth in rural areas of Bangladesh, coupled with a strong tradition of bequeathing land in fixed proportions to all male and female heirs, has led to increasing landlessness and extreme fragmentation of agricultural landholdings. Farm size now averages less than 1 hectare. Under these circumstances, it is not surprising that agricultural production has become highly intensive. Double or triple cropping is the norm in most areas, with the latter becoming increasingly common (Figure 3).

Intensification was made possible in large part by the introduction of irrigation technology. Over the past 25 years, cropping intensity has increased significantly, mostly as the result of a sharp increase in cultivation of irrigated land during the *rabi* season, which has resulted from the expansion of irrigation facilities, particularly systems served by tubewells (Figure 4). Government subsidies played an instrumental role in promoting the expansion of irrigation, although irrigation subsidies were reduced during the early 1990s.

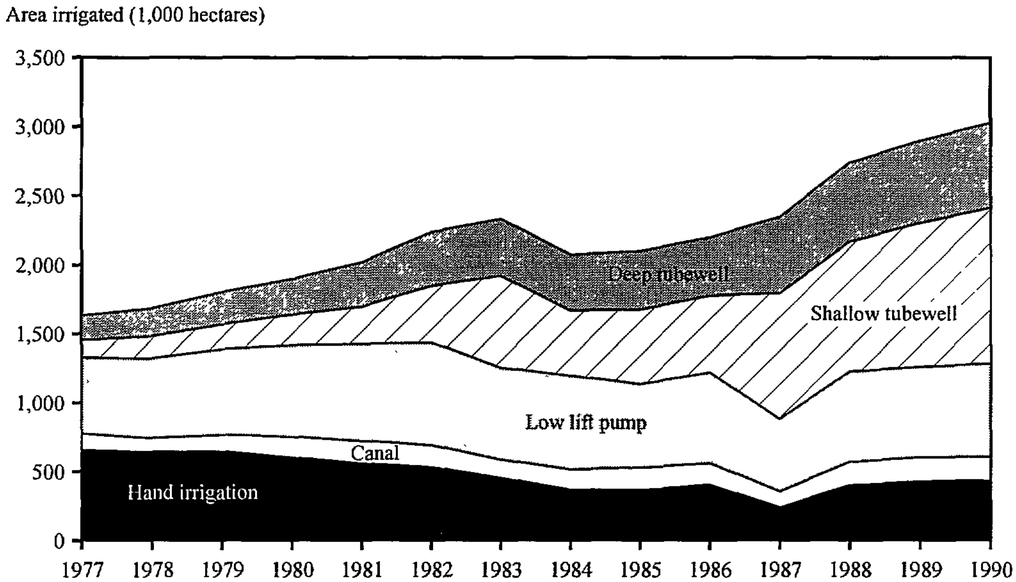
Micro-level variability in agroclimatic conditions has fostered the emergence of a large number of localized cropping patterns in Bangladesh. Most of these cropping patterns are dominated by cereals, which supply 80 percent of caloric and 60 percent of protein intake for the average household (World Bank 1992). In most areas of the country, the cropping pattern revolves around one, two, and sometimes even three rice crops,

Figure 3—Cropping intensity, 1992/93



Source: Bangladesh Bureau of Statistics.

Figure 4—Area under irrigation, by type of irrigation, 1977–90



Source: Bangladesh Bureau of Statistics.

reflecting the paramount importance of rice in the rural economy. The rice cropping calendar varies depending on variety (traditional versus modern), planting method (broadcast sowing versus transplanting), water regime (rainfed versus irrigated), and other factors. The first rice crop is the spring *aus* crop, which is planted during March and April during the early part of *kharif* season to benefit from the onset of the annual monsoon rains. The second and most important rice crop is the summer *aman* crop, which is grown in the middle of *kharif* season, during the period of heaviest rainfall when water supplies are most reliable. An early *aman* crop may be broadcast sown as early as April, while a late *aman* crop (usually following an *aus* crop) may be transplanted as late as July. The third rice crop is the winter *boro* crop, which is grown with irrigation during *rabi* season. *Boro* rice may be planted from late December all the way into early February, while the harvest ranges from April through June.

The cropping calendar is as complex for other crops as it is for rice. Sugarcane (which is grown year round) competes with *aus* and *aman* rice during *kharif* season in some areas. Jute (which is planted from April to May and harvested in August and September) can also compete with *aus* rice, while cotton (which is planted in July and August and harvested in February and March) may compete with late-planted *aman* rice. Wheat, pulses, oilseeds, roots and tubers, vegetables, and spices are all grown during the November to March period (*rabi* season) and thus are potential competitors for *boro* rice.

Livestock Production Activities

Cropping activities in Bangladesh are linked to livestock production through a two-way flow of products and services. The power furnished by draft animals is the principal source of nonhuman energy in the agricultural sector, with buffalo and cattle providing the energy for most heavy farm work, including land preparation, threshing, and transportation (Wennergren, Anhalt, and Whitaker 1984). Livestock and poultry also provide animal protein (milk, meat, and eggs) for consumers, and they generate cash income for rural households through the sale of food products, hides and skins, and manure (used for fertilizer or cooking fuel). Finally, in a nation where rural savings institutions remain underdeveloped (despite the much-publicized success of the Grameen Bank), livestock represent an important repository for savings as a hedge against possible future capital needs.

Since the scarcity of land generally precludes large-scale cultivation of commercial feed crops, livestock must subsist chiefly on a combination of natural forage and crop by-products, especially rice straw and polishings, pulse residues, and sugarcane tops. Although most rural households save crop by-products to feed to their own animals, surplus production is sometimes marketed, and prices for by-products used as feed are well established in most parts of the country. Whether used within the household as an intermediate input or sold for cash, crop by-products have an economic value that must be included in assessing the profitability of cropping activities.

Trends in Crop Production

Production data for Bangladesh's principal crops are presented in Tables 1 and 2. Rice is by far the most important cereal, accounting for approximately 75 percent of the total cultivated area. Wheat ranks second in importance among cereals, followed at a considerable distance by coarse grains such as millet, sorghum, and maize. Other important food crops include pulses, such as gram, mash, *kheshari, masur*, and mung; oilseeds, such as mustard, safflower, and sunflower; and potatoes. These are grown partly for home consumption and partly for sale. Sugarcane and jute are major commercial crops grown throughout the country, while tea, cotton, and tobacco are important in localized areas.

The past three decades have witnessed a shift in cultivated area away from fiber crops (particularly jute) and toward food crops. Growth in production of food crops, especially wheat and rice, has increased even more rapidly than the area planted to these two crops as a result of significant yield increases (Figure 5). These changes have been driven by increases in the relative profitability of rice and wheat following the introduction of high-yielding modern varieties (MVs).

Although Bangladesh's Green Revolution has led to much-needed increases in foodgrain production, some analysts have recently expressed concern that the increasing dominance of cereals in the cropping pattern is having adverse nutritional consequences for the large proportion of the rural population that relies primarily on its own production to meet household consumption requirements. Increasing apprehension

Table 1—Area planted in principal crops, Bangladesh, 1965–95

Year	Paddy	Wheat	Coarse grains	Oilseeds (primary)	Pulses	Potatoes	Jute	Sugarcane	Tea
				(1,000 hectares)					
1965	9,360	53	78	303	381	55	930	144	38
1966	9,075	55	79	331	410	61	893	153	40
1967	9,889	68	79	346	409	70	1,016	164	41
1968	9,742	78	111	352	387	76	916	167	42
1969	10,314	117	114	361	440	84	1,008	165	43
1970	9,913	120	114	337	451	85	938	166	46
1971	9,298	126	108	336	474	87	710	164	46
1972	9,630	127	101	311	567	76	914	140	46
1973	9,878	120	96	316	688	80	905	128	46
1974	9,792	123	97	318	803	80	593	147	43
1975	10,330	126	93	353	885	94	520	154	43
1976	9,882	150	91	351	1,053	96	660	133	43
1977	10,028	160	91	364	1,322	77	746	145	43
1978	10,102	189	81	408	1,142	90	847	154	43
1979	10,160	265	83	578	1,027	97	770	155	43
1980	10,309	433	76	574	978	96	642	151	44
1981	10,461	591	92	633	949	102	577	149	45
1982	10,586	534	62	625	871	108	582	161	45
1983	9,738	519	166	611	864	110	588	166	45
1984	10,223	526	146	609	792	110	683	167	45
1985	10,398	676	159	620	778	111	933	164	45
1986	10,609	540	155	596	738	108	1,066	160	46
1987	10,322	585	130	581	722	196	779	165	46
1988	10,224	597	114	582	737	123	518	173	46
1989	10,478	560	115	609	737	111	550	172	46
1990	10,435	592	113	617	734	117	561	186	47
1991	10,245	599	111	608	725	124	588	191	48
1992	10,178	575	108	614	719	128	589	187	48
1993	9,814	637	102	614	713	130	501	185	48
1994	9,908	615	98	610	713	131	485	181	48
1995	9,950	650	99	613	727	132	470	181	48

Source: FAO 1995.

over the trend toward ever more intensive rice cultivation has given rise to calls for diversification of the cropping pattern to improve nutrition levels, increase overall productivity, and spread risk (see, for example, Mahmud et al.1994).

Three points should be noted about the rice economy (Table 3). First, the *aman* crop is the most important rice crop, currently accounting for about 52 percent of total rice production, compared with 13 percent for the *aus* crop and 35 percent for the *boro* crop. Second, during the past two decades, the *boro* crop has increased dramatically in importance. The area planted in *boro* rice has grown rapidly with the expansion of irrigation (Figure 6). Because yields of *boro* rice are higher than those of the other rice crops, the *boro* crop accounts for a disproportionately large share of total production. Twenty years ago, the *boro* crop accounted for only 10 percent of total rice production; today, it accounts for more than 33 percent (Figure 7). Third, semidwarf MVs have steadily re-

Table 2—Production of principal crops, Bangladesh, 1965–95

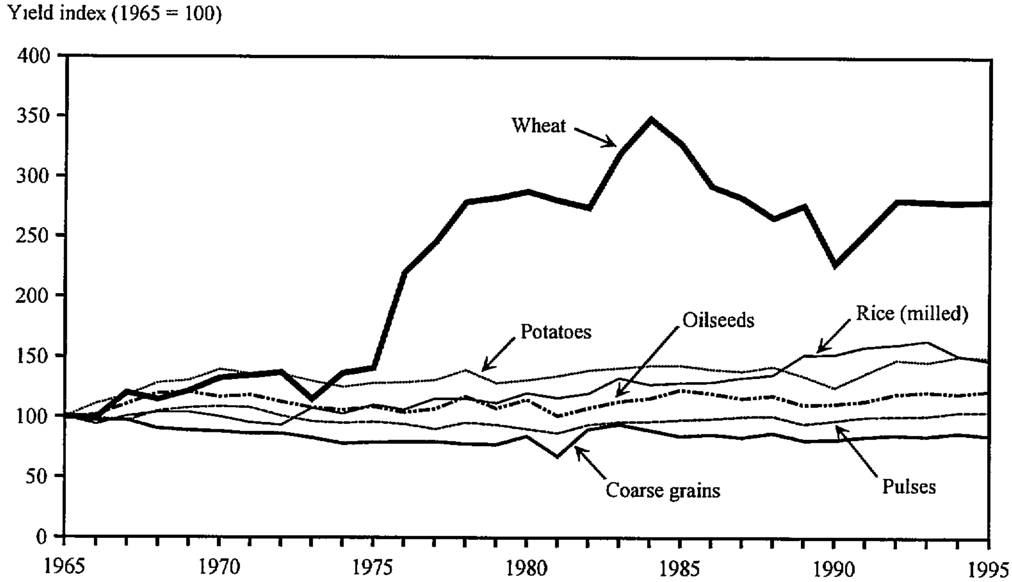
Year	Paddy	Wheat	Coarse grains	Oilseeds (primary)	Pulses	Potatoes	Jute	Sugarcane	Tea
				(1,000 metric tons)					
1965	15,751	35	67	64	273	401	1,369	6331	27
1966	14,363	36	66	71	292	494	1,278	7,671	29
1967	16,757	54	66	81	284	601	1,318	8,200	29
1968	17,016	59	86	89	291	712	1,078	7,711	29
1969	18,007	94	87	92	339	800	1,380	7,414	30
1970	16,715	105	86	83	351	865	1,257	7,519	31
1971	14,897	112	80	84	366	863	794	7,720	12
1972	15,134	115	75	74	410	753	1,222	5,777	24
1973	17,863	91	68	72	475	759	1,135	5,404	27
1974	16,930	111	65	71	547	730	736	6,443	32
1975	19,143	117	63	81	609	880	800	6,741	29
1976	17,628	218	62	77	711	903	884	5,981	34
1977	19,451	259	62	82	853	735	986	6,504	37
1978	19,582	348	54	101	781	914	1,186	6,777	38
1979	19,109	494	55	131	690	909	1,093	6,937	37
1980	20,821	823	55	139	632	917	904	6,676	40
1981	20,446	1,093	53	135	590	999	850	6,599	39
1982	21,325	967	48	142	585	1,095	892	7,136	41
1983	21,761	1,095	134	146	595	1,131	953	7,358	42
1984	21,933	1,211	112	149	547	1,148	935	7,169	38
1985	22,556	1,464	115	161	546	1,159	1,386	6,878	43
1986	23,110	1,042	114	151	522	1,103	1,580	6,640	38
1987	23,121	1,091	93	142	520	1,069	1,232	6,896	38
1988	23,316	1,048	85	145	533	1,276	882	7,207	41
1989	26,784	1,022	80	142	500	1,089	834	6,707	44
1990	26,778	890	79	145	512	1,066	856	7,423	39
1991	27,377	1,004	80	146	522	1,237	967	7,682	45
1992	27,510	1,065	79	155	520	1,379	958	7,446	46
1993	27,062	1,176	74	157	517	1,384	894	7,507	49
1994	25,248	1,131	73	154	533	1,438	797	7,601	51
1995	27,128	1,274	72	158	545	1,440	770	7,601	51

Source: FAO 1995.

placed tall traditional varieties (TVS). Between 1972/73 and 1992/93, the proportion of total rice area planted in MVs rose from 11 to 50 percent, while the proportion of MV paddy in total production rose from 25 to 66 percent.

Originally a minor crop, wheat has increased in importance during the past three decades as rising levels of imports (including large quantities of food aid) have led to rapid increases in wheat consumption. In the wake of the 1974 famine, farmers sharply increased the area planted in wheat (Chowdhury 1993b). Taking a cue from the farmers, government policymakers decided to encourage domestic production, partly to reduce reliance on wheat imports and partly to diversify domestic foodgrain supply away from rice. Wheat promotion efforts initiated during the mid-1970s led to further rapid expansion in the wheat area, much of it concentrated in the northern and central parts of the country.

Figure 5—Index of yields of principal food crops, 1965–95



Source: FAO, Agrostat-PC, crop production domain, 1995.

The growth rates underlying these figures are instructive. The surge in wheat production was concentrated during the late 1970s and early 1980s, coinciding with the government's campaign to promote the crop (Figure 8). Over a 10-year period, area planted in wheat increased at a rate of 15 percent per year from a very low base (Figure 9), while yields rose by more than 3 percent per year (Figure 10). These impressive rates of growth slowed dramatically during the late 1980s. Although the reasons for the slowdown are still debatable, two factors are frequently cited as having contributed to the deceleration in the expansion of wheat area and the stagnation of wheat yields. First, increased access to irrigation (resulting from government programs to develop irrigation infrastructure) encouraged many wheat growers to divert resources to irrigated *boro* rice. Second, the late 1980s corresponded to the period when subsidies were removed from many inputs; sudden sharp increases in input prices may have led wheat growers to cut back on use. Since peaking in 1984/85, wheat area and yields have remained flat.

As one of the world's largest recipients of food aid, much of which is given in the form of wheat, Bangladesh has been a consistent wheat importer. Although most Bangladeshi consumers exhibit a strong preference for rice, wheat imports are frequently relied upon to help overcome rice production shortfalls. Wheat is well suited for this purpose because it is reliably available in world markets, often at concessional prices due to chronic overproduction in the major exporting countries.

The expansion in wheat area and the growth in wheat yields realized during the late 1970s and early 1980s fueled a 10-fold increase in wheat production and led to a sharp reduction in the level of dependence on imports (Table 4). Whereas in the mid-1970s Bangladesh was producing only about 15 percent of its wheat requirements, by the early

Table 3—Area, yield, and production of three major rice crops, Bangladesh, 1971–91

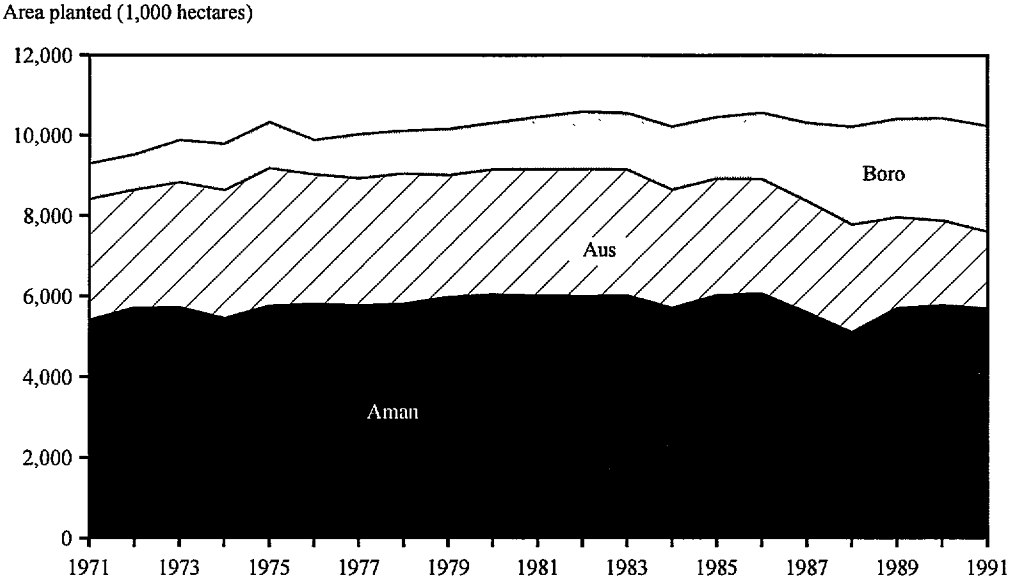
Year	*Aman*			*Aus*			*Boro*		
	Area	Yield	Production	Area	Yield	Production	Area	Yield	Production
	(1,000 hectares)	(tons/ hectare)	(1,000 tons)	(1,000 hectares)	(tons/ hectare)	(1,000 tons)	(1,000 hectares)	(tons/ hectare)	(1,000 tons)
1971	5,413	1.05	5,695	3,003	0.78	2,341	884	1.97	1,738
1972	5,714	0.98	5,587	2,930	0.78	2,272	885	2.10	2,071
1973	5,719	1.17	6,699	3,108	0.90	2,801	1,050	2.11	2,220
1974	5,451	1.10	6,000	3,179	0.90	2,859	1,161	1.94	2,250
1975	5,761	1.22	7,045	3,420	0.94	3,230	1,148	1.99	2,286
1976	5,809	1.19	6,906	3,218	0.94	3,010	855	1.93	1,650
1977	5,771	1.29	7,422	3,162	0.98	3,104	1,094	2.05	2,239
1978	5,809	1.28	7,429	3,236	1.02	3,288	1,072	1.80	1,929
1979	5,974	1.22	7,303	3,037	0.92	2,809	1,149	2.11	2,427
1980	6,038	1.32	7,964	3,112	1.06	3,289	1,160	2.27	2,630
1981	6,011	1.20	7,209	3,146	1.04	3,270	1,303	2.42	3,152
1982	5,995	1.25	7,516	3,159	0.97	3,067	1,433	2.47	3,546
1983	6,800	1.31	7,843	3,139	1.03	3,222	1,401	2.39	3,350
1984	5,711	1.39	7,930	2,938	0.95	2,783	1,575	2.48	3,909
1985	6,020	1.42	8,542	2,907	0.97	2,828	1,533	2.39	3,671
1986	6,054	1.37	8,267	2,859	1.09	3,130	1,652	2.43	4,010
1987	5,591	1.38	7,690	2,779	1.08	2,993	1,943	2.43	4,731
1988	5,101	1.34	6,857	2,684	1.06	2,856	2,439	2.39	5,831
1989	5,703	1.61	9,202	2,263	1.09	2,475	2,454	2.46	6,033
1990	5,777	1.59	9,167	2,108	1.07	2,261	2,548	2.10	5,357
1991	5,694	1.63	9,269	1,916	1.14	2,179	2,635	2.58	6,807

Source: Bangladesh Bureau of Statistics, various years.
Note: All tons are metric tons.

1990s about 45 percent of domestic consumption requirements were being met from local production. Yet even with these gains, wheat has never approached the importance of rice among locally produced cereals; at its peak, domestic wheat composed only 9 percent of total cereal production. Nonetheless, wheat has remained politically and economically important, because significant quantities must be imported to meet rising demand. In spite of the clear progress achieved in increasing domestic production, wheat and wheat flour imports continue to account for the bulk of Bangladesh's total foodgrain imports. In recent years, about 8–10 percent of total wheat imports have consisted of commercial imports, with the rest having been brought in as food aid. Just over 50 percent of all commercial wheat imports have originated in North America (either the United States or Canada), as has much of the wheat imported as food aid.

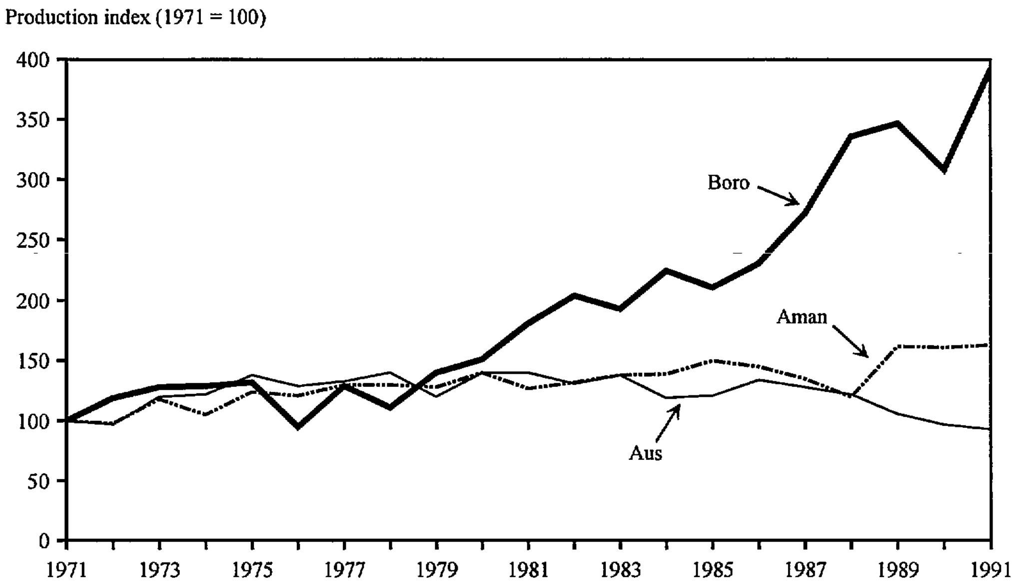
Projecting future levels of wheat imports is complicated by the difficulty of predicting wheat consumption levels. Although Bangladesh is generally thought of as a rice-eating nation, consumption of wheat has been growing steadily. From 1968 to 1988, per capita wheat consumption rose at an average annual rate of 3.6 percent. This consumption growth, which began following the introduction of wheat into the former East Pakistan (now Bangladesh), has been driven in part by the influx of wheat food aid since independence.

Figure 6—Area planted in rice, by cropping season, 1971–91



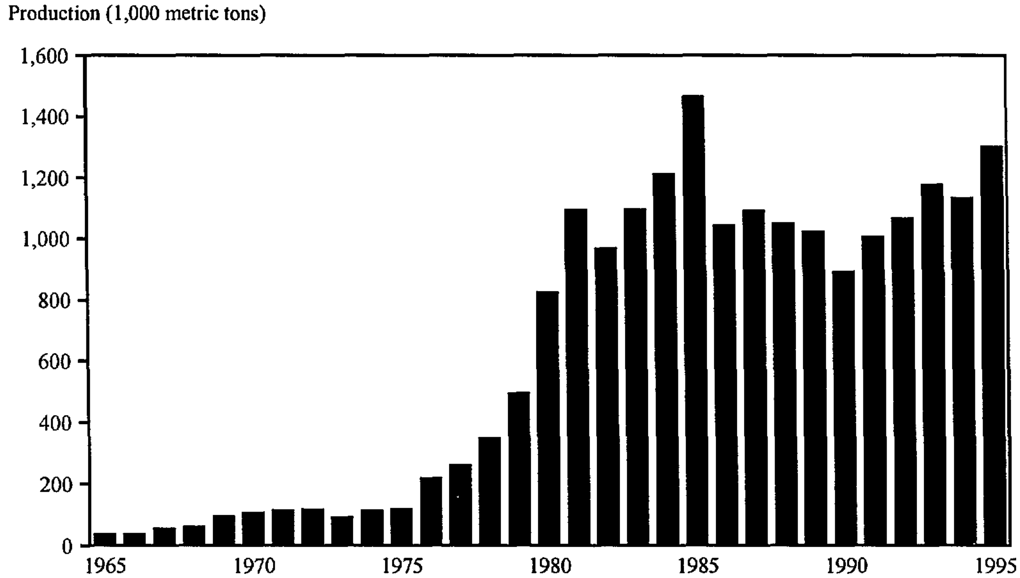
Source: Calculated from data in Table 3.

Figure 7—Trends in production of major rice crops, 1971–91



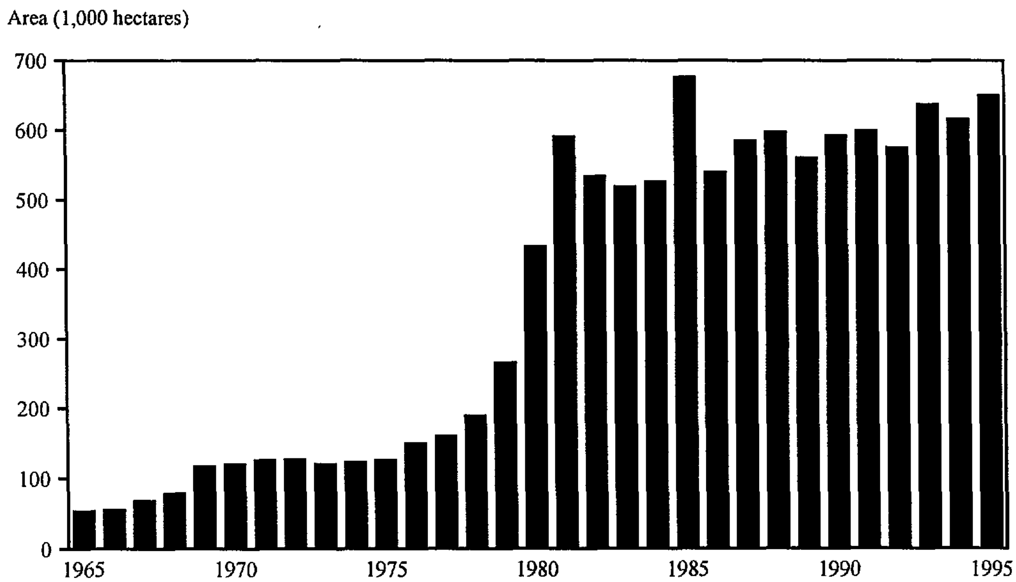
Source: Calculated from data in Table 3.

Figure 8—Wheat production, 1965–95



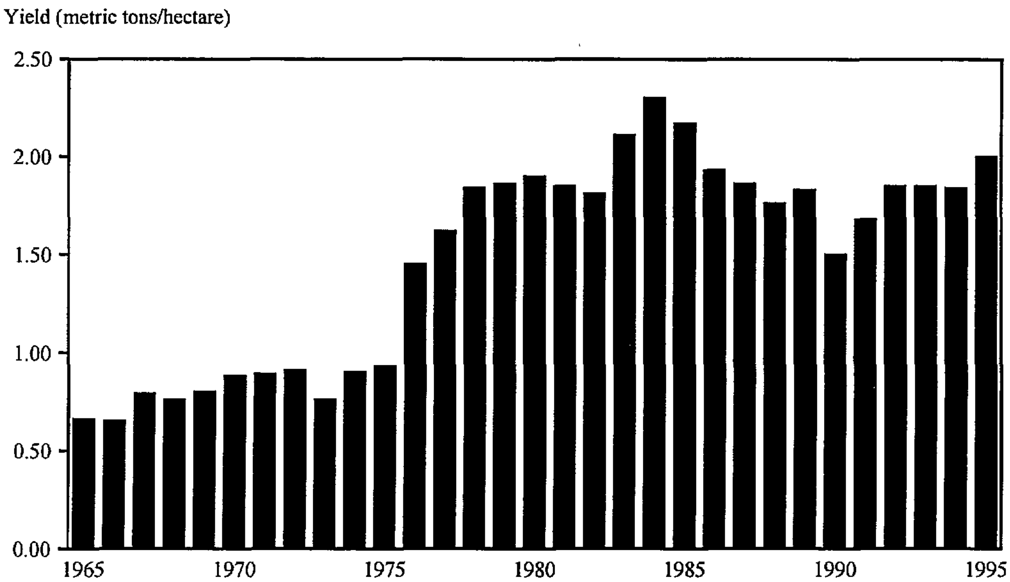
Source: FAO, Agrostat-PC, crops production domain, 1995.

Figure 9—Wheat area, 1965–95



Source: FAO, Agrostat-PC, crops production domain, 1995.

Figure 10—Wheat yields, 1965–95



Source: FAO, Agrostat-PC, crops production domain, 1995.

Wheat Production Zones

Five wheat production zones have been defined, based on farm-level data collected during the survey and geographical location (Figure 11). The Northwest (NW), North Central (NC), South Central (SC), and Southwest (SW) Zones include most of the nation's major wheat-growing areas, while the Northeast (NE) Zone represents an area of relatively low wheat production potential, which accounts for an insignificant portion of national production.

The definition of the five wheat production zones warrants explanation. The purpose of the zoning exercise was to stratify the sample into relatively homogeneous groups of households distinguished by their wheat production technologies (defined in terms of the types and quantities of inputs used). Two approaches were considered: (1) stratification based primarily on geographical location, and (2) stratification based primarily on technical factors likely to affect choice of wheat production technology (the water control regime, soil texture, and land elevation, for example). Both approaches have advantages and disadvantages. If stratification is done on the basis of geographical location, households falling within each stratum will not be completely homogeneous in terms of technical factors, but they are likely to face similar prices for inputs and outputs. If stratification is done on the basis of technical factors, households falling within each stratum may be widely distributed in space, so they are likely to face

Table 4—Wheat in the cereal economy of Bangladesh, 1970–95

Year	Wheat production	Wheat and flour imports	Paddy rice production	Milled rice imports	Wheat production as a percent of cereal production[a]	Wheat imports as a percent of cereal imports[a]
		(1,000 metric tons)			(percent)	
1965	35	241	15,751	82	< 1	75
1966	36	552	14,363	386	< 1	59
1967	54	679	16,757	439	< 1	60
1968	59	724	17,016	312	< 1	70
1969	94	933	18,007	240	< 1	79
1970	105	1,061	16,715	510	< 1	68
1971	112	817	14,897	348	1	70
1972	115	1,034	15,134	681	1	60
1973	91	2,506	17,863	396	< 1	86
1974	111	1,770	16,930	94	< 1	95
1975	117	2,268	19,143	282	< 1	89
1976	218	1,173	17,628	417	2	74
1977	259	382	19,451	104	2	78
1978	349	1,425	19,582	318	3	81
1979	494	918	19,109	38	4	95
1980	823	1,640	20,821	548	6	75
1981	1,093	876	20,446	79	7	92
1982	967	1,582	21,325	264	6	96
1983	1,095	1,515	21,761	317	7	83
1984	1,211	1,872	21,933	167	8	92
1985	1,464	1,905	22,556	677	9	74
1986	1,042	1,449	23,110	53	6	96
1987	1,091	1,511	23,121	260	7	85
1988	1,048	2,334	23,316	674	6	78
1989	1,022	2,151	26,784	63	5	97
1990	890	1,157	26,778	380	5	75
1991	1,004	1,606	27,377	16	5	99
1992	1,065	1,475	27,510	18	5	99
1993	1,176	1,034	27,062	21	6	97
1994	1,131	886	25,248	66	6	93
1995	1,274	1,754	27,128	813	7	68

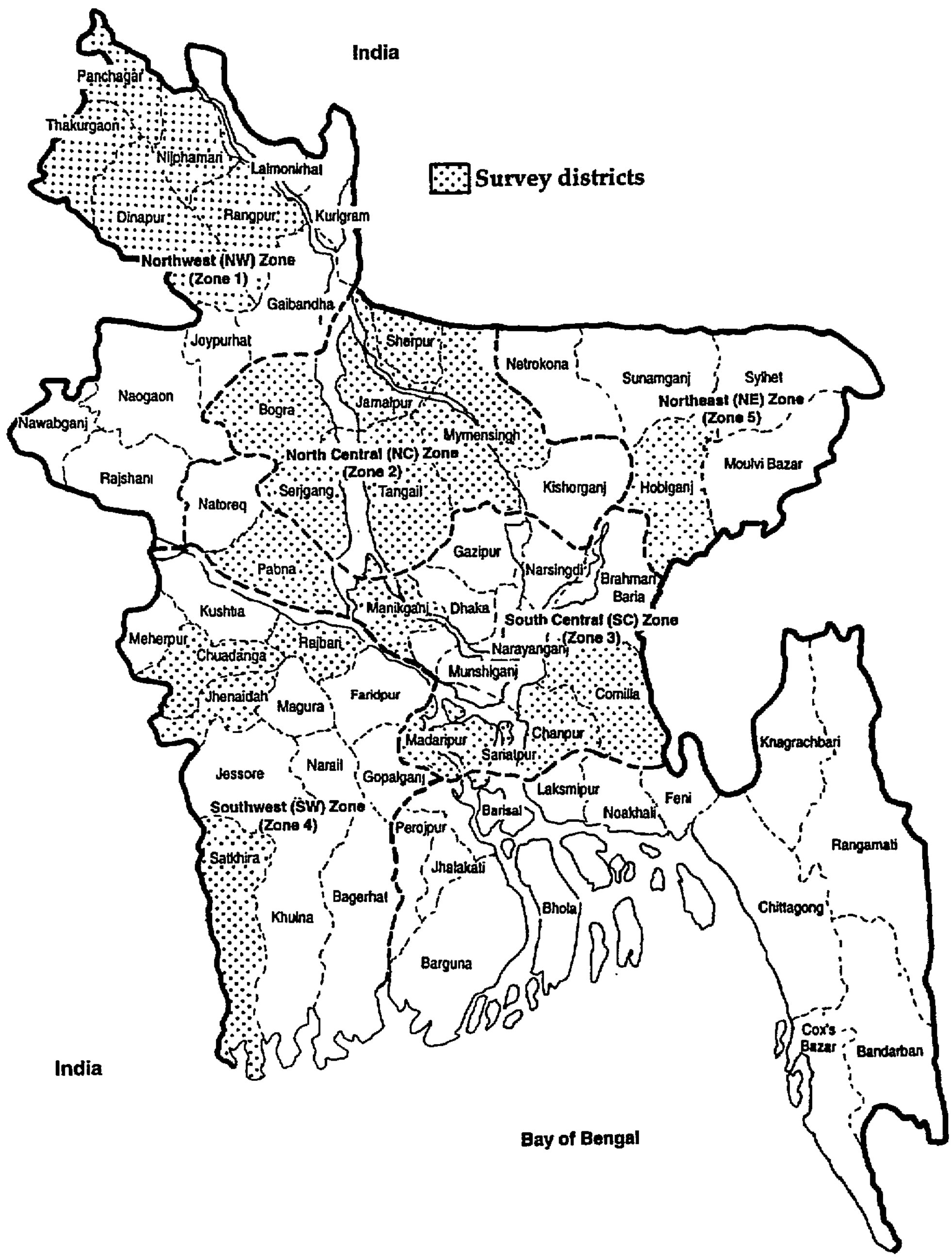
Source: FAO 1995.
[a]Total cereal production and imports calculated using milled rice equivalent.

a broad range of input and output prices (which will affect their choice of production technology).[7]

The first approach was eventually selected as the more practical, and the sample was stratified into wheat production zones primarily on the basis of geographical location. The boundaries of each production zone were drawn taking into account the farm-level data collected during the survey, that is, an effort was made to group subsets of

[7] The ideal solution would have been to stratify the sample on the basis of geographical location *and* technical factors. This was deemed impractical, as it would have required greatly expanding the sample size, possibly into the thousands.

Figure 11—Map of Bangladesh



households that were similar in agroclimatic circumstances, cropping patterns, and wheat production practices. Cluster analysis subsequently confirmed that many technical factors believed to affect choice of wheat production technology are highly correlated with geographical location (Table 5), so most of the households grouped together by the stratification procedure presumably use similar wheat production technologies. However, even though variability within zones is considerably lower than variability between zones, none of the production zones can be characterized as completely homogeneous. Therefore, the results are applicable to "representative" or "average" households in each zone, but they do not necessarily apply to all households.

When nonsurveyed districts are subjectively classified into one of the five zones, the importance of each zone in the national wheat economy becomes evident (Table 6). The NW, NC, SC, and SW Zones (Zones 1–4) include most of the nation's major wheat-growing areas, while the NE Zone (Zone 5) accounts for an insignificant portion of national wheat production.

Plot-level Factors Affecting Farmers' Planting Decisions

The data presented in Tables 4 and 5 reveal that wheat plots are not distributed randomly within each zone. For example, even though the SC Zone consists predomi-

Table 5—Characteristics of surveyed wheat plots, by wheat production zone

Zone	Land elevation		Soil texture		Irrigation status	
	High	Low	Light	Heavy	Irrigated	Nonirrigated
	(percent)					
1. Northwest (NW)	100	0	94	6	42	58
2. North Central (NC)	60	40	57	43	17	83
3. South Central (SC)	98	2	33	67	82	18
4. Southwest (SW)	96	4	54	46	26	74
5. Northeast (NE)	13	87	34	66	0	100

Source: CIMMYT–IFPRI producer survey, 1993.

Table 6—Wheat production zones of Bangladesh

Zone	Suitability for wheat	Predominant land elevation	Predominant soil texture	National wheat area	National wheat production	National wheat marketing
					(percent)	
1. NW	Very suitable	High	Light	27	28	27
2. NC	Suitable	High	Light – medium	22	22	16
3. SC	Suitable	Low	Light – medium	22	23	39
4. SW	Suitable	High	Medium – heavy	27	25	16
5. NE	Unsuitable	Low	Medium – heavy	2	1	2

Source: Compiled by the authors from data obtained from the Food and Agriculture Organization of the United Nations and the Bangladesh Bureau of Statistics.

nantly of low-lying land, 98 percent of the wheat plots surveyed in the SC Zone are located on land classified by farmers as "high." Plot-level data collected during the producer survey provide valuable insights into the factors that influence farmers' planting decisions. The 421 plots on which soils data were collected were stratified according to the crop being grown at the time of the survey (1992/93 *rabi* season) in order to highlight similarities and differences in irrigation status, land type, and soil texture. After the enumerator recorded whether each plot was irrigated or nonirrigated, the farmer was asked to rate the elevation of the land and to identify the predominant type of soil. Farmers readily distinguished between high-, medium-, and low-lying land. They also distinguished five main soil types, which can be ranked in increasing order of their capacity to retain water: *bele* (sandy loam), *bele-doash* (silt loam), *doash* (silt), *etel-doash* (silty clay loam), and *etel* (clay loam).

When plots are stratified according to their physical characteristics, it becomes clear that irrigation status, land elevation, and soil texture have an important influence on crop choice (Table 7). *Boro* rice tends to be planted in low-lying, heavy textured soils that tend to puddle and are easier (and cheaper) to irrigate. In contrast, irrigated wheat and nonirrigated food crops tend to be planted in high-lying, light-textured soils.

These conclusions are supported by the results of a simple exercise designed to shed light on farmers' planting decisions. The decision on whether to grow wheat is modeled using the logistic probability model (binomial logit model), which is often used when the response variable is discrete (Greene 1993). The reduced form of the model is given as

$$\text{Prob}\,[y_i = 1] = e\,\beta' X / (1 + e\,\beta' X), \tag{1}$$

Table 7—Characteristics of plots planted to *rabi* food crops, 1992/93

	Irrigated crops		Nonirrigated crops		
Characteristic	Wheat	*Boro* rice	Wheat	Oilseeds	Pulses
Scale (hectares)					
Average plot size	0.30	0.21	0.51	0.33	0.25
Land type (percent)					
High land	87.1	25.2	53.2	49.7	74.8
Medium land	8.8	39.1	25.4	28.0	13.0
Low land	4.1	35.4	21.3	22.4	12.2
Soil texture (percent)					
Sandy loam	0.1	0.1	1.7	1.6	3.6
Silt loam	31.5	11.8	44.3	12.7	42.0
Silt	35.3	16.9	31.2	12.5	19.7
Silty clay loam	29.0	38.6	14.3	30.4	20.8
Silty clay	4.1	32.7	8.4	42.9	14.0
Irrigation					
Mean number of irrigations	2	20	. . .	. . .	. . .

Source: CIMMYT–IFPRI producer survey, 1993.
Notes: Leaders (. . .) indicate not applicable. Percentages may not add to 100 because of rounding.

where

y_i = is the qualitative dependent variable that takes on the value 1 for wheat growers, 0 otherwise;

X = a matrix of explanatory variables related to the decision taken by farmer I to grow wheat; and

β' = the parameters to be estimated.

The decision to grow wheat is modeled as a function of the following variables:

ELEVATION	=	dummy variable for land elevation, where 1 = high land and 0 = medium or low land;
SOILTEXT	=	dummy variable for soil texture, where 1 = light texture (sandy loam, silt loam, silt), and 0 = heavy texture (silty clay loam, silty clay);
AREACULT	=	area cultivated by the farmer during the current cropping season;
WHEATPRICE	=	wheat selling price reported by the farmer[8]; and
BOROPRICE	=	*Boro* rice selling price reported by the farmer.[9]

The likelihood that a rural household grows wheat was hypothesized to be positively associated with agroclimatic factors that favor wheat production, particularly high land elevation (*ELEVATION*) and light soil texture (*SOILTEXT*). In addition, since the area planted to *boro* rice is apparently limited by resource constraints, the likelihood that a household grows wheat was hypothesized to increase with farm size (AREACULT), since farmers with large landholdings frequently will not be able to plant their entire farm to *boro* rice. Finally, economic theory suggests that the decision to grow wheat is positively associated with changes in wheat prices (*WHEATPRICE*) and inversely associated with changes in *boro* rice prices (*BOROPRICE*).[10]

According to the results of the logit analysis in Table 8, the estimated model has good explanatory power, as indicated by the number of correct predictions of wheat growers and nongrowers (84 percent). The log likelihood ratio (47.19 with 3 degrees of freedom) allows rejection of the null hypothesis with an extremely high degree of certainty. All five of the explanatory variables have the expected signs; of these, two (*ELEVATION* and *AREACULT*) are significant at the 1 percent level, and one (*SOILTEXT*) is significant at the 10 percent level. No significant relationship is found between the decision to grow wheat and the producer prices of wheat (*WHEATPRICE*)

[8] The *LIMDEP* software package used to estimate the model requires a complete data set, that is, if a data point is missing for any one variable, the entire case is excluded from the analysis. Consequently, if the plot in question was planted in *boro* rice and the farmer did not grow wheat in 1992/93, the average wheat selling price reported by other farmers in the same village is used.

[9] For the same reason given in footnote 7, if the plot in question was planted in wheat and the farmer did not grow *boro* rice in 1992/93, the average *boro* rice selling price reported by other farmers in the same village is used.

[10] *WHEATPRICE* and *BOROPRICE* are included as separate variables, rather than jointly in the form of a wheat-rice price ratio, because, if the hypothesis is correct that wheat and rice are not substitutes in production, the two prices can be expected to have independent effects. Somewhat surprisingly, wheat and *boro* rice selling prices within each village vary considerably, presumably reflecting differences in selling dates and in the ability of different households to negotiate favorable marketing terms.

Table 8—Factors affecting farmers' decision to grow wheat (logit model results)

Variable	Estimated coefficient	t-statistic
ELEVATION	1.395[a]	4.487
SOILTEXT	0.514[b]	1.803
AREACULT	0.004[a]	4.201
WHEATPRICE	0.001	0.150
BOROPRICE	–0.002	–0.449

Notes: Log likelihood function –165.5231
Restricted log likelihood –191.0215
Chi-squared 55.9968
Degrees of freedom 4
Significance level 0.0000
Percent of correctly predicted outcomes: 83 percent.
[a]Significant at the 1 percent level.
[b]Significant at the 10 percent level.

and *boro* rice (*BOROPRICE*). The lack of significant coefficients on the two price variables can be interpreted several ways. The apparent unimportance of output prices could indicate that the decision to grow wheat is driven by nonprice factors (since many households grow wheat primarily for home consumption, their production decisions are relatively insensitive to changes in market conditions). An alternative explanation is that the amount of variability present in these cross-sectional price data is insufficient to establish a clear relationship between wheat-growing behavior and prices. The ad-hoc procedure used to handle missing data (explained in footnotes 7 and 8) may also have contributed to the insignificant coefficients on the two price variables.

Wheat Production Technologies

For the profitability analysis, wheat production technologies are classified into rainfed technologies and irrigated technologies. In practice, the difference between the two is probably less pronounced than with other crops, since irrigated wheat receives on average only 2–3 irrigations (compared with an average of 20 irrigations for *boro* rice). Nonetheless, assured availability of irrigation water does influence crop management practices by reducing the risk of drought and justifying use of higher levels of purchased inputs, especially fertilizer.

Wheat production begins with land preparation activities. Following the harvesting of *kharif* crops, the soil is cultivated. Most tillage operations are carried out using animal-drawn implements, often the country plow and plank. Most farmers perform 5–7 plowings and 10–12 plankings (Ahmed 1992). Mechanized land preparation, relatively uncommon in the past, has been increasing in popularity: 29 percent of the total wheat area covered by the survey was cultivated using a power tiller or tractor. The number of tillage operations varies depending on the physical structure of the soil, the resources available to the farmer, and the urgency of completing land preparation in time to ensure timely planting.

Most wheat grown in Bangladesh is sown during late November or early December, with a small part of the crop planted as late as January. Seed is broadcast by hand and lightly covered with soil. Although the recommended seeding rates are 120 kilograms per hectare for irrigated conditions and 100 kilograms per hectare for nonirrigated conditions, most farmers seed at rates up to 150 kilograms per hectare to achieve desired plant populations. Among survey respondents, seeding rates for wheat were high in both irrigated and rainfed plots. Given the high seeding rates, seed is an important component of the total production cost.

Wheat seed is obtained from various sources. Over half of the wheat area covered by the survey was planted using the farmer's own seed (seed that the farmer had saved from the harvest of the previous season). About one-third of the area covered by the survey was planted with seed purchased from the Bangladesh Agricultural Development Corporation (BADC), a parastatal that produces and distributes certified seed of wheat and other major commodities. The remaining area was planted with seed obtained from non-BADC sources, generally other farmers.

Adoption of wheat MVs has been extensive (Table 9). Nearly 100 percent of the wheat area covered by the survey was planted in MVs.[11] Proportionally the greatest area was planted to Kanchan and Akbar, relatively new MVs released during the past 10 years, although a significant proportion of total wheat area is still sown to Sonalika, an old MV. Adoption of MVs has occurred across all farm size categories, with large-scale farmers tending to replace MVs more quickly. This pattern is consistent with adoption patterns observed in other countries and lends further support to the view that MVs represent a scale-neutral technology over the long term (Byerlee 1994).

As expected, widespread adoption of cereal MVs is associated with extensive use of fertilizer to maintain soil fertility. Both chemical fertilizer and farmyard manure are commonly used on both wheat and rice (Table 10). Among chemical fertilizers, nitrogen, phosphorus, and potassium are usually applied in single-nutrient form. Although

Table 9—Adoption of wheat modern varieties (MVs), by farm size, 1992/93

Farm size	Share of wheat area in this farm size category	Share of area in this farm size category planted in		
		Newer MVs[a]	Older MVs[b]	Total MVs
(hectares)	(percent)		(percent)	
Less than 0.2	28	65.4	34.0	99.4
0.2 – 0.5	40	67.0	32.2	99.2
0.5 – 1.0	19	74.6	25.4	100.0
More than 1.0	13	86.7	13.3	100.0
All farms	100	70.6	29.0	99.6

Source: CIMMYT–IFPRI wheat producer survey, 1993.
[a]Kanchan (released in 1983) and Akbar (released in 1983).
[b]Sonalika (released in 1973).

[11] Information on wheat varietal use was obtained from all households contacted during the original village census. Thus, the wheat varietal use data presented in Table 7 apply to an area much larger than that planted by the 421 survey respondents.

Table 10—Use of chemical fertilizer and manure on wheat and rice, 1992/93

Item	Nitrogen	Phosphorus (P_2O_5)	Potassium (K_2O)	Manure
Irrigated wheat				
Proportion of farmers using fertilizer (percent)	98	90	73	57
Recommended rate (kilograms/hectare)	80–100	80	40	5,000
Actual application rate (kilograms/hectare)[a]	75	50	25	7,900
Nonirrigated wheat				
Proportion of farmers using fertilizer (percent)	92	73	47	34
Recommended rate (kilograms/hectare)	60–80	80	40	5,000
Actual application rate (kilograms/hectare)[a]	59	40	14	6,800
Irrigated *boro* rice				
Proportion of farmers using fertilizer (percent)	99	82	62	36
Recommended rate (kilograms/hectare)	120	80	40	5,000
Actual application rate (kilograms/hectare)[a]	108	52	33	5,700

Source: CIMMYT-IFPRI producer survey, 1993.
[a]Actual application rate calculated is based only on plots where the fertilizer was applied.

application rates are generally lower than recommended, farmers apply more fertilizer to irrigated wheat than to nonirrigated wheat. Presumably this reflects their understanding that the irrigated crop is less susceptible to drought problems and therefore warrants greater application of inputs. Where available, farmyard manure is also applied to wheat and rice plots. Manure is spread across the surface of the plot and incorporated into the soil during land preparation operations.

Soil samples were collected from all of the wheat plots being cultivated by survey respondents at the time of the survey. Laboratory analysis revealed that all of the soil samples were at or below critical levels for essential plant nutrients required for sustainable crop cultivation (Table 11). While alluvial soils such as those found in many parts of Bangladesh are generally assumed to be rich in nutrients, these results indicate otherwise and suggest that further intensification of the cropping system will require that steps be taken to increase soil fertility.

Irrigation practices for wheat generally do not involve a high degree of management. In most cases, water is delivered via small canals from the source (generally a tubewell) directly to the plot, which is completely flooded to a depth of several centimeters. Most irrigated wheat plots receive only 2–3 irrigations (corresponding to 8–30 centimeters of water). These are usually applied shortly after planting to ensure good germination, even stand establishment, and vigorous early vegetative growth. In contrast to the relatively small number of irrigations given wheat, *boro* rice receives an average of 20 irrigations (corresponding to 90–125 centimeters of water). These are evenly distributed throughout the growing season and are particularly critical during the germination, stand establishment, flowering, and grain filling stages. A high level of management is required to maintain delivery canals during the *boro* rice season.

Use of pesticides on wheat to control insects is not recommended and therefore remains relatively uncommon. Only 7 percent of the wheat area covered by the survey was treated with chemical pesticides. However, use of pesticides to control insects in

Table 11—Fertility of soils in wheat plots

Element	Critical level	Average nutrient level in the sample	Samples at or below critical level
			(percent)
Nitrogen (NH_4^+–N)	75 ppm	24.40	100
Organic matter	2 percent	0.90	100
Zinc	2 ppm	1.60	85
Boron	0.2 ppm	0.21	69
Magnesium	0.8 meq/100 ml	1.90	28
Manganese	5 ppm	16.50	24
Calcium	2 meq/100 ml	5.70	23
Phosphorus	14 ppm	25.90	22
Copper	1 ppm	7.50	3
Sulfur	14 ppm	25.90	3
Potassium	0.2 meq/100 ml	0.38	2
Iron	10 ppm	121.00	1

Source: CIMMYT-IFPRI producer survey, 1993.

Notes: Ppm = parts per million, meq = milliequivalents, ml = milliliters.

boro rice is a recommended and often necessary practice. Pesticide use was found to be extensive in *boro* rice; 60 percent of the area planted in *boro* rice received pesticide treatment.

Wheat is harvested by hand from late February through early April, with most harvesting activity concentrated in March. Hired labor is often contracted to complete the harvest in timely fashion. Plants are cut near the base of the stem with a small harvesting knife, transported to a central location in the field or home, and threshed manually by beating. The grain is transported to the village for storage. Straw, which is stored either on the farm or in the village, is used as feed, fuel, or thatch.

CHAPTER 4

Financial Prices and Economic Prices

The budgets developed to determine the profitability of wheat versus alternative crops are estimated using two sets of prices. Financial prices (the actual market prices paid by farmers for inputs and received for outputs) are used to determine financial profitability. Economic prices (shadow prices representing the scarcity value of inputs and outputs in the Bangladeshi economy) are then substituted for the financial prices to determine economic profitability.

Financial prices were collected as part of the producer survey and thus represent prices actually paid and received by farmers during the 1992–93 *rabi* season. Economic prices are calculated by the authors using the procedures described in this chapter. Tradables and domestic resources are treated separately, because different procedures are used in establishing economic prices for these two distinct categories of goods.

Financial and economic prices used to carry out the baseline runs of the profitability analysis are based on prices prevailing during the 1992/93 season, since the input-output parameters collected by means of the producer survey corresponded to that period. However, in the case of rice, 1992/93 prices are known to have deviated significantly from long-term trend prices, so the average market price prevailing during the previous three years is used as the financial price.[12] In the sensitivity analysis, various other prices are used to explore the likely effects of changes in the rice price.

[12] When price data collected during the survey were compared with data collected in preceding years through surveys carried out under the Bangladesh Food Policy Research Project, simple visual inspection revealed that input and output prices prevailing in 1992/93 were unexceptional. This is not surprising, since key climatic variables affecting crop production fell within normal ranges during the 1992/93 *rabi* season and since markets for purchased inputs functioned without major disruptions. Market prices of fertilizer, irrigation equipment, and fuel were higher than in previous years, but the rises can be attributed to ongoing efforts to remove subsidies on these inputs. The only important price that appears to have diverged from its long-term trend is the price of rice, which during its 1992/93 *rabi* season failed to recover from its usual postharvest low.

Tradable Goods

Tradable goods are those that can be imported or exported. Examples of tradables include production inputs (such as seed, fertilizer, tractors, and irrigation pumps) and production outputs (such as rice, wheat, and oilseeds). Economic prices for tradables are determined by their value in the international market, since these reflect the value of the tradables to the national economy.

In this study, economic prices for all agricultural outputs and all inputs except land, labor, and capital are estimated based on their value in the international market. Usually this involves calculating the appropriate import or export parity price. In a few cases where parity prices are difficult to compute because no clear trading pattern is evident, the domestic market-clearing price is used, with appropriate adjustments for significant distortions attributable to government policies or market failures (price controls, taxes, subsidies, and exchange rate distortions, for example).

Exchange Rate Effects

In estimating economic prices for tradables, it is important to take into account the prevailing exchange rate policy. Exchange rate policy can have a strong influence on the incentives afforded to individual production activities. Overvaluation of a country's exchange rate (relative to the currencies used by its major trading partners) imposes a tax on the production of tradable goods and a subsidy on consumption. Consequently, in calculating economic prices for tradables, it is necessary to recognize and correct for exchange rate distortions. Significantly, exchange rate distortions may have dissimilar effects on production activities that differ in their use of tradable inputs or their production of tradable outputs.

In recent years, the government of Bangladesh has pursued a relatively flexible exchange rate policy. The taka was put under a managed float system beginning in the late 1970s, with a secondary foreign exchange market introduced beginning in 1976. Despite the basic flexibility in the exchange rate determination mechanism, however, rigidities associated mostly with trade controls led to some misalignment in the official exchange rate (Rahman 1994).

Following Rahman (1994), a trade-weighted purchasing power parity approach is used to measure the degree of misalignment in the taka. The world price of traded goods is estimated using an average of the wholesale price indexes of Bangladesh's 17 largest trading partners, weighted by the average share of trade from 1973/74 to 1991/92. The domestic price of nontraded goods is estimated using the consumer price index, which presumably includes a larger proportion of nontraded goods than the wholesale price index. The base year used is 1985/86, the year when the official exchange rate was brought into approximate alignment with the real exchange rate through a devaluation. Based on the results of this procedure, the baseline profitability analysis is carried out using an exchange rate conversion factor of 0.85 to correct for an estimated 18 percent overvaluation of the taka. This parameter is then varied to determine whether the value assumed has an important influence on the results of the study.

Tradable Outputs

The four principal commodities considered in this study are all classified as tradable: wheat, rice, oilseeds, and pulses, as are by-products derived from these four commodities (such as straw and bran).

Wheat. As indicated earlier, during recent decades Bangladesh has been a consistent importer of wheat. Since approximately two-thirds of all wheat imported into Bangladesh is soft white wheat originating from the United States and Canada, the import parity price calculations for wheat are based on the reference price of North American No. 1 soft white winter wheat (f.o.b. Vancouver). In 1992, this stood at about US$145 per metric ton.[13] Despite recent improvements in the quality of Bangladeshi wheat, millers still consider domestic wheat inferior to imported wheat. Domestic wheat is therefore priced at a 10 percent discount relative to imported wheat.[14] No quality distinction is made here between irrigated and rainfed wheat, since these are not distinguished by millers.

The import parity price calculations for wheat appear in Appendix 2, Table 27. The international reference price is converted to taka at the shadow exchange rate and adjusted for domestic handling, processing, and transportation costs to derive the import parity price at the farmgate. Separate import parity prices are estimated for each of the five zones. Marketing and processing costs are obtained from a 1992/93 survey of wheat marketing costs (Chowdhury 1993b). In the baseline profitability analysis, the final consumption point for wheat is assumed to be the Dhaka wholesale market, which is the appropriate point of comparison for locally produced wheat that is marketed. Recognizing that some wheat-producing zones are net buyers of cereals during certain periods of the year, a second set of import parity prices is calculated in which the final consumption point is assumed to be the farmgate, which is an appropriate point of comparison for wheat produced for home consumption. The difference between the two sets of import parity prices (arising from transport and handling costs incurred in moving wheat between the farmgate and the Dhaka wholesale market) averages about 15 percent.

Although the baseline profitability analysis uses an import parity price for wheat based on the international reference price, a significant portion of international trade in wheat takes place at prices other than the reference price. Direct and indirect subsidies paid by major wheat exporters to help dispose of surplus production effectively reduce the net price paid by many importers. In recent years, Bangladeshi traders have often been able to take advantage of these subsidies; for example, most of the wheat imported commercially in 1993 benefited from subsidies averaging US$50 per ton[15]. To the extent that the international reference price of wheat overstates the discounted prices actu-

[13] In this report, all tons are metric tons.

[14] Bangladeshi wheat averages 12 percent protein content, as compared with 12.5 percent for most imported wheat. The 10 percent price discount used in calculating the import parity price probably penalizes Bangladeshi wheat more than is warranted.

[15] R. Pierce, personal communication, May 1994.

ally paid for commercial imports, its use in the profitability analysis favors wheat. Consequently, adoption of some sort of net international reference price (reflecting an expected subsidy or discount) might be appropriate.

Unfortunately, estimating such a price is not easy. The World Bank and the U.S. Department of Agriculture (USDA) have for some time been predicting that wheat export subsidies will decrease significantly following the implementation of reforms agreed upon during the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) (these reforms call for significant reductions in trade-distorting policies). Wheat prices indeed rose sharply in late 1995 and early 1996, but not for the reason cited by the World Bank and USDA; rather, prices rose in response to a sharp decline in global wheat stocks attributable to a series of bad harvests in major exporting countries and increased demand from China. On balance, it is still too early to tell whether high international wheat prices will be sustained; prices have already fallen from their 1996 highs, and analysts are predicting further decreases when the policy reforms enacted by the U.S. Congress take effect.

Because of the difficulty of predicting future international wheat prices and wheat export subsidies, the international reference price is used for the baseline scenario. Alternative reference prices for wheat are then explored in the sensitivity analysis.

Rice. Although Bangladesh has traditionally imported rice, imports have decreased dramatically in the wake of recent production gains. With the exception of 1995, when extraordinarily poor weather devastated the main *aman* crop, rice imports have been negligible during the past few years, and Bangladesh can no longer be characterized as a consistent rice importer. Many observers feel that if long-term trends continue, the nation will soon become self-sufficient in rice. A recent study concludes that exports will become necessary in the future to dispose of rice surpluses (Goletti 1994).

In the absence of a clear-cut trading pattern, there is no theoretical reason to refer to international reference prices in determining the economic price for rice. Nevertheless, the import and the export parity prices remain useful indicators, because they define the limits of the range within which domestic market-clearing equilibrium prices may fluctuate. The export parity price amounts to a price floor for rice farmers, because demand at the export parity price can be assumed to be infinitely elastic. Similarly, the import parity price imposes an effective ceiling: should the domestic price rise to the import parity level, imports would be triggered. Given the uncertainty about the long-term trading status of rice, import and export parity prices are calculated to provide a range of possible economic prices for rice.

Among the grades of rice produced in Bangladesh, the benchmark grade chosen for the study is coarse rice, since two-thirds of total domestic production and three-quarters of marketed surplus consist of coarse grades (Chowdhury 1992b, 1993c). Choice of coarse rice as the benchmark is further justified by the fact that virtually 100 percent of the *boro* rice crop—the crop that competes most directly with wheat—consists of coarse varieties harvested amid relatively wet conditions. Rainfall during the harvest period frequently leads to inconsistency in drying practices and affects grain quality characteristics such as color, moisture content, and percentage of broken grains.

Since most of the rice marketed in Bangladesh is milled with 15 percent broken grains, the import parity price calculations for rice are based on the reference price of Thai milled white rice, 15 percent broken (f.o.b. Bangkok). In 1992, this stood at US$245 per ton. However, this grade of Thai rice does not correspond exactly to the rice produced in Bangladesh, almost all of which is parboiled.[16] Parboiling has a clear effect on quality, decreasing the percentage of broken grains but conferring undesirable consumption qualities that often result in price discounting (Chowdhury 1993c). Based on pricing patterns observed in five important wholesale markets in Bangladesh, an 8 percent discount is applied to the reference price to reflect the inferior quality of parboiled rice.

The import parity price calculations for rice appear in Appendix 2, Table 28. The international reference price is converted to taka at the shadow exchange rate and adjusted for domestic handling, processing, and transportation costs to derive the import parity price at the farmgate. Once again, separate import parity prices are estimated for each of the five zones. The final consumption point for rice is assumed to be the Dhaka wholesale market.

In the export parity price calculations for rice (Appendix 2, Table 29), the international reference price is based on prices actually received by private traders in 1992 for exports of parboiled Bangladeshi rice.[17] Since these negotiated prices correspond exactly to the rice being exported, no additional discounting is necessary.

Although calculation of the import and export parity prices serves to establish the ranges for the economic price of rice, the baseline profitability analysis uses an adjusted domestic market price.[18] Given free trade and without policy-induced distortions, the domestic market-clearing price will reflect the scarcity value of a good. It is important to note, however, that these conditions do not prevail in Bangladesh. In 1992/93, the period during which the price data for this study were collected, large public foodgrain stocks were crowding out private storage activity and significantly depressing market prices for rice, as speculators sold on the expectation of future sales from government stocks (Chowdhury 1993a). Rice prices during this period were well below their medium term trend. Under the assumption that government intervention in the rice market was causing downward pressure on prices, market prices are adjusted upward by 10 percent to bring them in line with medium-term trend prices (Haggblade and Rahman 1993).

Oilseeds. Of the many oilseeds grown in Bangladesh, mustard is the most important. Although mustard seed is rarely traded in international markets, a close substitute in international trade is rapeseed. Since the early 1980s, Bangladesh's imports of oilseeds (mainly rapeseed) have increased from 20,000 tons to 80,000 tons (World Bank 1993a). Major import sources for Bangladesh include France, Canada, and more recently

---

[16] Unparboiled rice is exacting in its paddy quality requirements; parboiled rice is less so.

[17] Exports of Bangladeshi rice have been modest, in part because parboiled rice attracts few buyers in international markets.

[18] Where a commodity alternates between being imported and exported, some analysts have advocated using an average of import and export parity prices as the economic price (Ahmed 1988). However, there is no theoretical basis for this approach, which can lead to errors where there are policies that alter the country's trade pattern. See Byerlee and Morris 1993.

Poland and China. The import parity price for oilseeds is based on the reference price of rapeseed. In 1992, this stood at about US$274 per ton.

The import parity price calculations for oilseeds appear in Appendix 2, Table 30. The international reference price (adjusted to account for ocean freight, insurance, and handling charges) is converted to taka at the shadow exchange rate and adjusted for domestic handling, processing, and transportation costs to derive the import parity price at the farmgate. Once again, separate import parity prices are estimated for each of the five zones. The final consumption point for oilseeds is assumed to be the Dhaka wholesale market.

Pulses. *Masur*, a type of red lentil, is the most important pulse produced in Bangladesh.[19] *Masur* is used as the representative pulse in the profitability analysis. The import parity price for pulses is based on the reference price of red lentils. In 1992, this stood at US$440 per ton. Table 31 in Appendix 2 presents the import parity price calculations for pulses. The international reference price for red lentils is converted to taka at the shadow exchange rate and adjusted for domestic handling, processing, and transportation costs to derive the import parity price at the farmgate. Once again, separate import parity prices are estimated for each of the five zones. The final consumption point for pulses is assumed to be the Dhaka wholesale market.

Tradable Inputs

All production inputs other than domestic resources (land, labor, and capital) are classified as tradable or potentially tradable. In calculating economic prices for tradable inputs, the approach used is similar to that used for tradable outputs: market prices reported by the survey respondents are adjusted to correct for distortions resulting from government policies or market failures or both. The tradable component of all inputs (100 percent in many cases but less for mixed inputs containing a labor component, such as machinery maintenance and repair services) is multiplied by the exchange rate conversion factor to compensate for the overvaluation of the taka. However, because of the laboriousness of calculating economic prices, additional adjustments are made only in cases where a significant distortion is thought to be present.[20] Parity prices are formally calculated only for muriate of potash (MP) and triple superphosphate (TSP). For several minor tradable inputs known to benefit from direct or indirect government subsidies (such as pesticides and veterinary supplies), ad hoc procedures are used in estimating economic prices. Typically this involves adjusting the market price upward by 10 percent.

Fertilizer. Most of the nitrogen fertilizer used in Bangladesh is produced locally, whereas virtually all phosphorus and potassium fertilizers are imported. Over the past decade, responsibility for fertilizer marketing has been transferred away from the public sector and

---

[19] Mung, *khesari*, and *maskalai* are other popular pulses. Of the three, *khesari* is banned from international trade due to its association with a disease called lathyrism. *Maskalai*, whose nearest substitute is the dan pea from Australia, is a relatively minor crop.

[20] Experience has shown that calculation of economic prices is usually not warranted for purchased inputs that account for a relatively small portion of production costs (Morris 1989).

put into the hands of a decentralized, semi-privatized system involving both state organizations and private traders. Until 1978, fertilizer procurement and distribution down to the *thana* level were monopolized by the Bangladesh Agricultural Development Corporation (BADC). Appointed private dealers purchased fertilizer from BADC at administered prices set well below cost and were supposed to sell at a specified margin. However, the official prices proved impossible to administer effectively, with the result that subsidies intended to reach farmers were often appropriated by the dealers, who were able to use their monopoly power to manipulate the prices with immunity. Between 1979 and 1983, this system was replaced by one in which BADC maintained only its wholesale distribution functions; retail distribution was ceded entirely to the private sector. Over time, BADC's role in fertilizer distribution was further reduced, to the point where domestic procurement of urea, most imports of phosphorus and potassium, and all distribution are currently being handled by private traders.

The price of urea continues to be set administratively, which is possible because production is controlled by the government. Subsidies supposedly were eliminated in 1985, but since adjustments to the issue price lagged well behind inflation, a subsidy reappeared within a few years. A series of price increases introduced during the early 1990s finally succeeded in eliminating all subsidies on urea. Meanwhile, since imports and distribution of TSP and MP have become entirely privatized, prices of these two fertilizers closely follow global prices.

Although Bangladesh exports urea, exports take place only because official wholesale prices for urea charged by the government-owned factories are set well below the cost of production. If prices for Bangladeshi urea were set at the actual cost of production, exports would cease.[21] Therefore, for the purposes of this study, urea is considered a nontraded tradable, and the domestic market price is used as the basis for determining the economic price.

Import parity prices are calculated for TSP and MP. The parity price calculations appear in Appendix 2, Tables 32 and 33. International reference prices are converted to taka at the shadow exchange rate and adjusted for domestic handling, processing, and transportation costs to derive parity prices at the farmgate. As for the parity prices estimated for tradable outputs, separate prices are estimated for each of the five zones. The final consumption point for fertilizers is assumed to be the farmgate in each zone.

Seed. Among the sample farmers, use of purchased seed varied considerably between crops. Although most farmers reported purchasing wheat and mustard seed, they often saved seed of rice and pulses from own production. For purchased seed, the market is assumed to be reasonably competitive, and the only adjustment made to the market price is to multiply it by the exchange rate conversion factor to compensate for exchange-rate-induced distortions incurred during seed production. For farmer-produced (own) seed, a 25 percent price premium is applied to the price at which the farmer reported selling grain to reflect the additional cost involved in selecting, harvest-

[21] For a discussion of the problems involved in estimating economic prices in the presence of trade-distorting policies, see Byerlee and Morris 1993.

ing, cleaning, and storing own seed. This higher price is then multiplied by the exchange rate conversion factor.

Agricultural machinery. Machinery use reported by sample farmers includes mechanized land preparation (using power tillers or tractors), irrigation (using pumps), and transport (using tractors or lorries). Simple capital budgets are developed for each category of machinery, based on standard capital budgeting procedures and assuming straight-line depreciation, to permit estimation of hourly operating costs for each type of machinery (see Appendix 2, Table 34). Where appropriate, adjustments are then made to tradable components of the hourly operating costs to compensate for exchange-rate induced distortions. For example, all imported components of agricultural machinery are multiplied by the exchange rate conversion factor. (Diesel fuel, electricity, and operator's labor costs are adjusted using the specific conversion factors described elsewhere.)

Animal traction. Many sample farmers reported that they perform land preparation, tillage, and cultivation operations using animal traction. A simple capital budget is developed to estimate the daily cost of operating a bullock team. This budget is based on the actual cost of purchasing a bullock team and standard coefficients for work capacity and feed requirements are used (see Appendix 2, Table 34).

Irrigation. Irrigation systems in Bangladesh can be divided into five types: (1) gravity systems (in which water is raised with the help of medium- to large-scale dams and diverted through canals into farmers' fields); (2) deep tubewell (DTW) systems (in which water is pumped from depths of 50–130 meters by a large, centrally managed pumping facility and distributed across a "command area" of between 10 and 24 hectares); (3) shallow tubewell (STW) systems (in which water is pumped from depths of 10–50 meters by a small, easily transportable pump, which is usually situated within the farm that receives the water); (4) low-lift pump (LLP) systems (in which water is raised 1–10 meters from a canal, river, or surface reservoir); and (5) human-powered systems (in which water is lifted by hand- or foot-operated devices from depths of less than 10 meters and distributed among adjacent plots). Of the five types of systems, DTW and STW systems are the most important for the production of wheat and rice.

Ownership and management of DTW and STW systems differ. Most DTWs currently operating were constructed during the 1970s and early 1980s with the help of extensive government subsidies. The typical DTW system consists of a medium-sized (35–50 horsepower) pump mounted on a platform and housed inside a permanent concrete or cinder block structure. Initially, most of these DTWs were operated by government irrigation management authorities, which charged farmers a fixed annual fee for irrigation services. These fees reflected a heavy degree of subsidy, since they were designed only to recapture operating costs. In addition, operating costs themselves were considerably reduced because of extensive subsidies to electricity and diesel fuel. In recent years, the irrigation authority has sought to reduce its operating deficit by selling DTW systems to private interests. Today most DTWs are privately owned and operated, frequently along lines similar to those followed by the government irrigation authorities in earlier years. However, profitable operation of DTWs (which because of their relatively large pumping capacity require a large command area in order to operate efficiently) has been made increasingly difficult by the diversification of cropping patterns and the increasing fragmentation of landholdings.

In contrast to DTWs, most STWs have always been privately owned and operated. The typical STW system consists of a small (12 horsepower) diesel or electric pump mounted on a mobile platform and sheltered under a temporary structure. For many years, the government discouraged installation of STWs by maintaining extremely high import tariffs, arguing that the more centralized management associated with DTWs would make it easier to manage irrigation rationally, and that cost savings could be achieved through economies of scale. Siting restrictions also affected where STWs could be installed. However, by the mid 1980s the advantages of STWs were becoming increasingly apparent; in an attempt to promote their use, taxes on small diesel engines were slashed, and other nontariff barriers to imports were removed in 1988 (World Bank 1993a). The effects of this change in policy were dramatic. Private import and distribution of small diesel engines accelerated, and the area under STW systems expanded rapidly (Guisselquist 1992).

Today, most farmers who irrigate during *rabi* season either own a small pump or rent water from a neighboring STW or DTW system. Private water charges vary significantly. The variability in water charges seems to be a function of the type of irrigation system providing the water (STW versus DTW), the source of power for pumping (diesel versus electricity), the age and condition of the pump, and possibly the presence of alternative sources of supply. In the baseline runs of the profitability analysis, financial irrigation costs are estimated based on the actual water charges reported by farmers. However, given the difficulty of accounting for location-specific factors affecting water charges, no attempt is made to estimate economic prices by adjusting the market prices reported in each zone. Instead, capital budgets are developed for a representative STW and DTW. Purchase prices and salvage values are obtained from commercial distributors, while technical operating coefficients are taken from Mott MacDonald 1990. For STWs, these parameters are verified by means of a randomly selected sample of 52 STW operators, who were questioned about the costs of purchasing and operating their STW. After import duties and other taxes are subtracted from the purchase price of tradable components, these are then multiplied by the exchange rate conversion factor to compensate for exchange-rate induced distortions in prices. Based on these budgets, it is possible to estimate economic costs associated with the use of each type of pump (see additional details in Appendix 2, Table 34).

In this study, irrigation costs for the various irrigated crops are calculated based on the number of hours the pump is actually operated. This approach accurately reflects the irrigation costs supported by pump *owners*, whose expenses vary in direct proportion to the use of the machinery. By contrast, pump *renters* generally do not pay charges based on the number of pumping hours; rather, pump renters tend to negotiate contracts for the use of a pump throughout an entire cropping season. Although the cost of a seasonal contract for irrigating *boro* tends to be somewhat higher than the cost of a seasonal contract for irrigating wheat, the difference in costs is not nearly proportional to the difference in actual usage (18–22 irrigations for *boro* rice versus 2–3 irrigations for wheat). Even allowing for fixed costs associated with negotiating and securing a rental contract, relocating the pump, and so forth, market prices for water in effect subsidize irrigation services for *boro* rice and tax irrigation services for wheat. The approach used in this study of assigning irrigation costs on the basis of actual pumping hours avoids the hidden transfers implicit in market prices for water.

Diesel fuel. The market price of diesel fuel (used chiefly by irrigation pumps and transport) is multiplied by a conversion factor of 0.85 to compensate for an average 15 percent taxation. The diesel conversion factor is derived by updating the work of Shahabuddin and Rahman (1992).

Electricity. The market price of electricity is multiplied by an electricity conversion factor of 1.56 to compensate for continuing government subsidies to electricity users. The electricity conversion factor also is derived by updating the work of Shahabuddin and Rahman (1992).

Domestic Resources

Since domestic resources are nontradable, economic prices for domestic resources cannot be determined based on international reference prices. Economic prices for domestic resources therefore must be determined based on their marginal value product in a distortion-free environment (which is usually unobservable), or on their opportunity cost value (their value in the most profitable alternative use).[22]

Labor

Agricultural labor in Bangladesh can be divided into three categories: (1) family labor (unpaid family members who work on the farm); (2) attached farm labor (hired laborers who are employed for longer periods, often under annual contracts, and who live on the farm and perform a wide range of tasks); and (3) casual labor (workers who are hired, usually on a short-term basis, to perform a specific task or set of tasks). These three categories of labor are remunerated in different ways. Family labor generally does not receive cash wages; rather, family members share in the consumption of crops produced on the farm or receive some part of the cash proceeds realized from sales or both. Attached farm labor generally receives accommodation, food, and clothing as well as some cash wages. Casual labor usually works for a cash wage or a share of the crop, with meals sometimes included as part of the arrangement. In this study, wage rates are estimated separately for these three categories of labor.

[22] Barring distortions, when an economy is in equilibrium, the marginal value product will be equal to the opportunity cost value.

Theoretically, in a perfectly competitive market unencumbered by government-induced policy distortions, the economic price of a unit of labor should be equal to its marginal value product. Therefore, in cases where labor markets are relatively unregulated and reasonably competitive, market wage rates can serve as reliable proxies for economic wage rates. Unfortunately, however, conditions approaching perfect competition rarely prevail in the real world, as institutional rigidities, lack of access to information, and other factors frequently result in wage "stickiness." Under these circumstances, market wages may diverge significantly from the economic value of labor, and it becomes necessary to make adjustments to market wages in order to arrive at economic wages.

The market for agricultural labor in Bangladesh cannot be considered perfectly competitive, at least not throughout the entire year. During periods of peak labor demand (corresponding roughly to the periods when rice is planted and harvested), work is abundantly available, and the market approaches something close to a competitive situation as employers bid for the services of casual laborers. Numerous surveys, including the one carried out as part of this study, confirm that market wages rise noticeably during these periods of peak labor demand (Gotsch and Brown 1980; Shahabuddin and Rahman 1992). However, during periods of low demand for labor, institutional rigidities prevent market wages from falling as much as they should to clear the labor market, and unemployment results.[23]

Economic wage rates for each of the three categories of labor (family labor, attached farm labor, and casual labor) are determined separately for two groups of cropping operations, distinguished according to whether they occur during peak or slack labor demand periods. During peak labor demand periods, the labor market is reasonably competitive, so that market prices are assumed to reflect the economic scarcity value of labor. During slack labor demand periods, wages are considered to be too high (due to institutional rigidities that prevent wages from adjusting fully to changes in supply and demand conditions). Market wage rates recorded during the survey (comprising cash wages, payments in kind, and contributions of food and clothing) are converted to economic wage rates using a method derived by Shahabuddin and Rahman (1992) from a procedure first described by Gotsch and Brown (1980).[24] In the baseline profitability analysis, a conversion factor of 0.5 is used to convert from market wage rates to economic wage rates for operations during periods of slack labor demand.[25]

---

[23] An alternative explanation for the rise in unemployment observed during the slack season is that wages are prevented from falling by supply-side considerations, such as leisure loss or other costs of working (calorie consumption, and transactions costs, for example).

[24] The method involves calculation of expected wage rates, estimated by multiplying the observed market rate times the probability of finding employment. Data used for the estimation procedure are obtained from a survey of 679 farm households drawn from 21 districts of the country (for details, see Chowdhury 1992a).

[25] Given the difficulty of verifying the assumption that rising unemployment during slack labor periods is attributable to wage stickiness, use of a conversion coefficient of 0.5 may seem unjustified. However, sensitivity analysis subsequently confirmed that the profitability rankings among crops are robust under a wide range of shadow wage rates, indicating that the size of the conversion coefficient does not really matter too much. (see pp. 57–59).

Capital

Following standard budgeting practice, purchased inputs are assigned an opportunity cost of capital representing potential income forgone during the cropping season from capital tied up in purchased inputs. For the financial profitability analysis, a market interest rate of 15 percent is used in calculating the opportunity cost of capital. For the economic profitability analysis, an inflation rate of 3 percent is subtracted from the market interest rate to arrive at a real opportunity cost of capital of 12 percent.[26]

Land

Pricing land proved to be quite a challenge. Although efforts were made during the producer surveys to collect information on land prices, the results were unsatisfactory. Sales of agricultural land in Bangladesh are rare, so that within the sample the number of observable land transactions was too small to permit estimation of land prices with any degree of confidence. Rental of agricultural land is much more common, but land rental frequently involves complicated sharecropping arrangements in which the owner and the renter contribute varying proportions of the production inputs, while the production is shared in varying proportions that depend, among other factors, on the social relationship between owner and renter, on their respective contributions to inputs, and on the size of the harvest.

In the absence of an observable market for land, an approach based on the opportunity cost is adopted, in this case defined in terms of alternative use value. Under this approach, land used for production of a particular crop is assigned an opportunity cost equal to its value in the production of the most profitable alternative crop, with a distinction made between irrigable and nonirrigable land. Thus, irrigable land is assigned an opportunity cost equal to the net returns to land from the production of the most profitable alternative crop, irrigated or nonirrigated (since irrigated and nonirrigated crops both can be grown on irrigable land). Nonirrigable land is assigned an opportunity cost equal to the net returns to land from the production of the most profitable alternative nonirrigated crop (since irrigated crops cannot be grown on nonirrigable land).[27]

Effects of Government Policies on Prices

Before turning to the results of the profitability analysis, a review of the effects of government policies on incentives facing agricultural producers is in order. In the absence of government interventions or market failures, domestic prices of tradables can be expected to be closely related to world prices (adjusted for transportation and handling

[26] To the extent that this admittedly crude approach underestimates the true opportunity cost of capital, the results favor capital-intensive crops (for example, irrigated crops, especially *boro* rice) and discriminate against the rest.

[27] Strictly speaking this residual value reflects the returns to land *and to the farmer's management.* To the extent that differences in each farmer's management ability differentially affect the profitability of alternative crops, this method may introduce a distortion. However, considering the basic similarities in the management of the alternative production technologies being compared in this case, this difference is unlikely to be important.

costs). Government policies and market distortions affect production incentives by driving a wedge between actual market prices and the prices that would prevail given free trade and an equilibrium exchange rate.

The nominal protection coefficient (NPC) is the simplest measure of this wedge:

$$NPC = (P_d / P_w),$$

where

P_d = domestic price, and

P_w = world price (converted at an appropriate exchange rate and adjusted for quality differences, transport, and handling and storage costs).[28]

The NPC indicates the degree to which domestic prices differ from world prices. For outputs, an NPC greater than 1 implies that government policies in aggregate encourage production (since the domestic price received by producers is higher than the world price), whereas an NPC less than 1 implies that government policies in aggregate discourage production (since the domestic price received by producers is lower than the world price). For inputs, the direction of protection indicated by the NPC is reversed. For inputs, an NPC less than 1 implies that government policies in aggregate encourage use of the input, whereas an NPC greater than 1 implies that government policies in aggregate discourage use of the input.

Several overall trends are evident in the NPCs for major *rabi* food crops (wheat, rice, oilseeds, and pulses) during the period 1981/82–1991/92 (Table 12). During the first half of the 1980s, NPCs for all four crops consistently remained below 1, indicating that producer price policy was implicitly taxing farmers. This implicit taxation was at least partially offset, however, by subsidies on inputs (especially fertilizer and irrigation).[29]

During the mid-1980s, NPCs for rice, pulses, and oilseeds often rose above 1, indicating that growers of these crops were being extended protection through favorable producer price policies. The glaring exception was wheat, whose price remained well below the import parity price. Reasons for the low wheat prices are subject to debate. Since the government of Bangladesh has not intervened directly in wheat markets to force down producer prices, many analysts point the finger of blame at large annual influxes of wheat food aid and subsidized commercial imports, arguing that these must be having a depressing effect on market prices. Recent studies by Dorosh and Haggblade (1996) and by Ahmed et al. (1996) independently conclude that wheat food aid has depressed wheat prices by 12–13 percent. Other analysts point out that wheat food aid does not necessarily depress wheat prices, asserting that if it is carefully targeted to the poorest households, what amounts to an increase in income for these households can

[28] NPCs calculated using shadow exchange rates are sometimes referred to as "adjusted NPCs" to distinguish them from NPCs calculated using market exchange rates.

[29] Calculation of more complete measures of protection, such as effective protection coefficients (EPCs), is precluded by the impossibility of assembling time series data on past subsidies to key inputs (such as irrigation infrastructure, machinery, diesel fuel and electricity, and selected fertilizers and pesticides).

potentially increase their effective demand for wheat in the market and leave prices unchanged, if not actually strengthened. However, even strong proponents of wheat food aid concede that if aid is poorly targeted, or if wheat used in food-for-work programs or sold to finance government expenditures is released into the market during inopportune periods (immediately following the domestic harvest, for example), wheat aid can lower domestic production incentives. This point is corroborated by Dorosh and Haggblade (1996) who conclude that the net demand that is created by food aid is too small to absorb the supply increases associated with food aid imports and distribution.

Beginning in 1987/88, NPCs for all four crops once again fell below 1. Interestingly, this decline in producer prices during the late 1980s occurred against a backdrop of steady rollbacks in agricultural subsidies, meaning that the profit equation was being squeezed both on the output side and on the input side. Fortunately for producers and consumers, however, productivity gains more than offset the price effects, as the fall in output prices and the concurrent rise in input prices coincided with the introduction of input market reforms that provided farmers with access to cost-saving technology (Chowdhury 1994a; Haggblade 1994). The fruits of this phenomenon were shared with the rest of the economy through declining real prices.

NPCs for TSP, also in Table 12, have consistently stayed below 1, reflecting a history of subsidies and overvaluation of the exchange rate.

Table 12—Nominal protection coefficients (NPCs) for selected crops and fertilizers, 1981/82–1991/92

Year	Rice	Wheat	Pulses (lentils)	Oilseeds (rapeseeds)	Fertilizer (TSP)
1981/82	0.70	0.73	0.84	0.95	n.c.
1982/83	0.83	0.76	0.88	0.90	0.64
1983/84	0.98	0.78	0.69	0.93	0.73
1984/85	0.96	0.75	0.66	1.13	0.74
1985/86	1.04	0.79	0.75	1.42	0.77
1986/87	1.02	0.81	1.01	1.57	0.73
1987/88	1.06	0.83	1.07	1.70	0.73
1988/89	0.93	0.80	1.00	1.59	0.71
1989/90	0.86	0.84	0.78	1.73	0.68
1990/91	0.83	0.87	n.c.	n.c.	0.68
1991/92	0.79	0.88	n.c.	n.c.	0.76

Sources: Rice, wheat, and triple superphosphate (TSP) computed by the authors; lentils and rapeseeds from Mahmud et al. 1994.

Note: N.c. is not computed.

CHAPTER 5

Profitability Measures

In this chapter, the financial and economic profitability of competing production activities is compared in each of the five zones to determine the degree to which government policies and market failure may have caused financial profitability to diverge from economic profitability.

Financial Profitability

Budgets are developed for two irrigated crops (wheat and *boro* rice) and for three rainfed crops (wheat, oilseeds, and pulses). Separate sets of budgets are developed for each of the five zones to allow for regional differences in production technology. In the baseline runs, the input-output coefficients correspond to the most common production technologies (use of animal traction for land preparation and STW for irrigation), and production costs are based on the assumption that both the bullock team and the STW are owned by the farmer.[30] (The complete budgets are presented in Appendix 2, Tables 35 to 49).

Table 13 summarizes the results of the baseline runs of the financial profitability analysis. In irrigated plots, *boro* rice is clearly the most profitable crop, generating higher financial returns to farmers' labor and management and to land than wheat in all four zones in which both crops are grown. In absolute terms, the profitability advantage enjoyed by *boro* rice is extremely large. (The advantage is least pronounced in the SC Zone, where yields of *boro* rice are relatively low and where labor costs are relatively high.)

In nonirrigated plots, the results of the financial profitability analysis vary considerably between zones. Pulses dominate among rainfed crops in the NW, SC, and SW Zones, although the profitability advantage is pronounced only in the SC Zone. Oilseeds dominate in the NC and NE Zones, with the advantage particularly pronounced in the NE Zone. Nowhere is rainfed wheat shown as the most profitable crop, although the financial returns to wheat approach those of at least one of the other crops in most zones.

[30] An additional advantage of using the results of the capital budget analysis to cost out animal traction and irrigation services is that possible distortions in rental markets for these two important factors of production are avoided.

Table 13—Financial returns to farmers' management, land in *rabi* crops

Zone	Irrigated crops: Wheat	Irrigated crops: *Boro* rice	Nonirrigated crops: Wheat	Nonirrigated crops: Oilseeds	Nonirrigated crops: Pulses
			(Tk/hectare)		
NW	2,111	16,552	2,224	2,125	2,810
NC	3,418	17,128	4,993	9,839	4,018
SC	4,529	9,566	3,195	3,327	6,541
SW	1,696	13,664	3,604	6,631	7,792
NE	. . .	3,515	1,835	17,979	. . .

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.

Notes: Leaders (. . .) indicate a nil or negligible amount. Prices for all crops except *boro* rice are 1992/93 prices. Returns to *boro* rice production were calculated using adjusted long-run trend prices (see the explanation in the text).

These results are consistent with farmers' behavior. In irrigated plots, *boro* rice is the most profitable option, which is why farmers tend to plant *boro* rice wherever land type and soil texture are appropriate and where irrigation is assured. (The only exception is the NE Zone, where rainfed oilseeds dominate all other crops, including *boro* rice.) In financial terms, wheat is not nearly as profitable as *boro* rice. Although input costs for *boro* rice are nearly twice as high as for wheat (primarily because of the much greater irrigation and fertility requirements), higher input costs are more than offset by higher yields. These results confirm the widely held view that *boro* rice is more profitable for farmers than wheat and explain the dramatic expansion that has occurred over the past 10 years in the area planted to *boro* rice.

In nonirrigated plots, the relative financial profitability of the three rainfed crops varies between zones, with no single crop exhibiting clear dominance. Pulses and oilseeds often are more profitable than wheat, but the advantage is rarely pronounced, except in the NE Zone.

Based on these results, it is reasonable to ask: Why do farmers in Bangladesh grow any wheat at all, if the financial returns to wheat production are everywhere exceeded by the returns to production of at least one other crop?

Three factors explain why farmers may be acting rationally in choosing to grow wheat: First, it is likely that wheat production is financially attractive for some households. The technical coefficients and prices used in the budgets are averages calculated across groups of respondents. These averages mask considerable variability between individual respondents. For some households, facing slightly different agroclimatic circumstances, endowed with different bundles of resources, possessing different management skills, and paying different prices for inputs and receiving different prices for outputs, wheat production undoubtedly is the most profitable option. Although in this study the size of the sample unfortunately is not large enough to allow development of separate budgets for different categories of wheat-growing households within each zone, clear evidence of the financial profitability of wheat production appears in the work of Uddin, Talukder, and Alam (1994), who report that wheat appears in the optimal cropping plan for a sample of farms in Mymemsingh District (NC Zone).

Second, even when wheat does not generate the highest net returns per unit of land area, growing wheat can be economically rational if households face resource constraints (and have limited access to credit). Just over 11 percent of the survey respondents indicated that their decision to plant wheat in 1992/93 was motivated mainly by the lower investment required in inputs for wheat production. Many of these households evidently did not have sufficient resources to plant all of their land to *boro* rice; faced with the choice of planting a small area to highly profitable rice or a large area to moderately profitable wheat, they chose to plant wheat in order to maximize total net returns. This conclusion is also supported by the work of Uddin, Talukder, and Alam (1994), whose analysis based on linear programming shows that the area planted to wheat can be expected to rise sharply where there are capital restrictions that limit the farmer's ability to expand the area under capital intensive crops (*boro* rice and vegetables).

Third, two-fifths of the survey respondents stated that the main reason for growing wheat is to lessen exposure to possible food shortages in March and April, the "hungry season" before the *boro* rice harvest. Rice and wheat are usually available in the market during the hungry season, but prices rise significantly during this period as traders' stocks are drawn down, making reliance on market purchases unattractive. Lacking the cash resources needed to purchase food during this critical period, many rural households choose to grow wheat in order to have food on hand prior to the *boro* harvest.[31] This explanation is supported by Ahmed et al. (1996, 50), who report that "many farmers grow wheat to meet their home consumption needs of cereals during the season before the *Boro* rice is harvested, regardless of economic factors."

Economic Profitability

The crop budgets are recalculated using economic prices to determine the economic profitability of the five cropping alternatives. As in the earlier financial profitability analysis, in the baseline runs the input-output coefficients once again correspond to the most common production technologies (use of animal traction for land preparation and STWs for irrigation), and production costs are based on the assumption that both the bullock team and the STW are owned by the farmer. However, due to the uncertainty about the appropriate economic price to use for rice, economic returns to *boro* rice production are estimated using three different prices: (1) the import parity price (appropriate if Bangladesh continues to be a net rice importer), (2) the long-run trend market price (appropriate if Bangladesh becomes self-sufficient in rice over the long run, and implicitly assuming that domestic market prices are relatively undistorted), and (3) the export parity price (appropriate if Bangladesh becomes a net rice exporter).

Table 14 summarizes the results of the baseline runs of the economic profitability analysis. Probably the most striking result is how the economic profitability of *boro* rice production varies depending on the price used for rice. When import parity prices are

[31] That so many respondents reported growing wheat to provide food during the hungry season suggests that, for many rural households, grain storage options are limited and credit markets are ineffective. Otherwise, these households would choose to grow rice, which they could store until needed during the hungry season, or sell and convert into consumption credit.

Table 14—Economic returns to farmers' management, land in *rabi* crops

	Irrigated crops				Nonirrigated crops		
	Wheat	*Boro* rice			Wheat	Oilseeds	Pulses
Zone	Import parity	Import parity	Market price	Export parity	Import parity	Import parity	Import parity
				(Tk/hectare)			
NW	8,450	32,616	17,664	9,624	7,911	1,043	3,866
NC	10,141	30,229	18,453	9,599	9,948	7,527	4,105
SC	12,736	23,316	11,227	4,496	7,285	2,852	5,958
SW	7,895	23,550	15,015	5,312	8,322	6,046	7,412
NE	. . .	10,234	4,591	1,292	6,625	13,542	. . .

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.
Note: Leaders (. . .) indicate a nil or negligible amount.

used, *boro* rice is clearly the most profitable crop in irrigated plots, generating significantly higher economic returns to farmers' labor and management and to land than wheat in all four zones in which both crops are grown. When long-run trend market prices are used, the net returns to *boro* rice production decline, and in the SC Zone, irrigated wheat displaces *boro* rice as the most profitable crop. When export parity prices are used, the profitability of *boro* rice production declines even further, with net returns falling below those for wheat in three zones (NC, SC, SW).

In nonirrigated plots, the results of the economic profitability analysis again show considerable variability. When economic prices are used, wheat increases in profitability relative to the other crops. Wheat ranks first in profitability in all zones except the NE Zone, where oilseeds once again emerge as the most profitable rainfed crop. As in the financial profitability analysis, no single crop consistently dominates the nonirrigated plots across all five zones, indicating that the profitability rankings are quite sensitive to local conditions and suggesting that farmers are wise to diversify.

These results of the economic profitability analysis have three important implications. (1) When production inputs and outputs are costed at their economic scarcity value, *boro* rice production frequently generates the highest economic returns to farmers' labor and management and to land. However, the economic profitability advantage of *boro* rice production depends on the nation's trading status. Production of *boro* rice is particularly profitable as long as Bangladesh remains a net rice importer, in which case the alternative to domestic production of *boro* is reliance on expensive commercial imports. Production of *boro* rice becomes less profitable once national self-sufficiency in rice is achieved and the domestic price begins to fall (as modeled under the baseline scenario, which corresponds to current reality). Under these conditions, *boro* rice maintains its profitability edge in four of the five zones, but irrigated wheat ranks first in economic profitability in the SC Zone, where much of Bangladesh's wheat production is currently concentrated. Should domestic rice production increase to such an extent that the domestic consumption requirements are met, so that the only way to dispose of rice surpluses is through exports, any further production of *boro* rice would be less profitable than production of irrigated wheat in the NC, SC, and SW Zones. (2) In nonirrigated plots, wheat ranks first in economic profitability in all zones except the NE Zone. (3) In economic returns, rainfed wheat can be as profitable or more profitable than irrigated wheat. Economic returns to rainfed wheat production actually exceed economic returns to irrigated wheat production in one zone and are quite similar in two others; only in the SC Zone does irrigated wheat production show a clear advantage in profitability. This result stems largely from the fact that under the agronomic conditions prevailing in Bangladesh, the yield gain in wheat attributable to irrigation is usually quite small (which is not surprising, considering that most irrigated wheat receives only two irrigations).

Effects of Government Policies on Profitability

Since the financial and economic budgets are calculated using the same input-output coefficients, any divergence between financial and economic profitability results from differences in financial and economic prices attributable to government policies and market failures. Tables 15–19 show the divergence between financial and economic returns to the production of each crop in each zone (using long-run trend market prices of rice as the economic price of rice). The net effect of government policies and market failures can be seen in column 3 in each of the tables. Financial profitability is lower than economic profitability for irrigated wheat, irrigated *boro* rice, rainfed wheat, and rainfed pulses (in two out of the four zones where pulses are grown), indicating that producers of these crops on the whole are taxed by government policies and market failures. Only in the case of rainfed oilseeds is financial profitability higher than economic profitability, indicating that, in general, government policies provide assistance to the production of oilseeds. The figures in column 3 can be disaggregated to show the

Table 15—Sources of differences between financial and economic profitability (NW Zone)

				Differences resulting from policies or market failures affecting				
Crop	Financial profitability[a] (1)	Economic profitability[a] (2)	Difference (3)	Producer prices (4)	Irrigation costs[b] (5)	Input prices (6)	Labor costs (7)	Other costs (8)
				(Tk/hectare)				
Irrigated crops								
Wheat	2,111	8,450	(6,339)	(6,183)	(70)	55	(135)	(6)
Boro rice	16,552	17,664	(1,113)	. . .	(597)	91	(566)	(41)
Rainfed crops								
Wheat	2,224	7,911	(5,687)	(5,607)	n.a.	(17)	(60)	(3)
Oilseeds	2,125	1,043	1,082	1,017	n.a.	63	0	2
Pulses	2,810	3,866	(1,057)	(607)	n.a.	(61)	. . .	. . .

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.

Notes: Leaders (. . .) indicate a nil or negligible amount. N.a. indicates "not applicable." Numbers in parentheses indicate implicit taxes.

[a]Financial and economic profitability of *boro* rice is calculated using the long-run trend market price as the price of *boro* rice.

[b]Irrigation is assumed to be provided by farmer-owned shallow tubewell (STW).

Table 16—Sources of differences between financial and economic profitability (NC Zone)

Crop	Financial profitability[a] (1)	Economic profitability[a] (2)	Difference (3)	Differences resulting from policies or market failures affecting: Producer prices (4)	Irrigation costs[b] (5)	Input prices (6)	Labor costs (7)	Other costs (8)
				(Tk/hectare)				
Irrigated crops								
Wheat	3,418	10,141	(6,723)	(6,262)	(72)	2	(372)	(18)
Boro rice	17,127	18,453	(1,325)	. . .	(517)	(100)	(659)	(50)
Rainfed crops								
Wheat	4,993	9,948	(4,956)	(4,767)	n.a.	(86)	(95)	(8)
Oilseeds	9,839	7,527	2,312	2,132	n.a.	218	(45)	7
Pulses	4,018	4,105	(87)	(19)	n.a.	(49)	(16)	(3)

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.

Notes: Leaders (. . .) indicate a nil or negligible amount. N.a. indicates "not applicable." Numbers in parentheses indicate implicit taxes.

[a]Financial and economic profitability of *boro* rice is calculated using the long-run trend market price as the price of *boro* rice.

[b]Irrigation is assumed to be provided by farmer-owned shallow tubewell (STW).

Table 17—Sources of differences between financial and economic profitability (SC Zone)

Crop	Financial profitability[a] (1)	Economic profitability[a] (2)	Difference (3)	Differences resulting from policies or market failures affecting: Producer prices (4)	Irrigation costs[b] (5)	Input prices (6)	Labor costs (7)	Other costs (8)
				(Tk/hectare)				
Irrigated crops								
Wheat	4,529	12,736	(8,207)	(7,986)	(140)	(4)	(69)	(8)
Boro rice	9,566	11,227	(1,661)	. . .	(619)	10	(989)	(63)
Rainfed crops								
Wheat	3,195	7,285	(4,090)	(3,989)	n.a.	(52)	(45)	(4)
Oilseeds	3,327	2,852	475	511	n.a.	(2)	(33)	(1)
Pulses	6,541	5,958	583	756	n.a.	(97)	(71)	(5)

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.

Notes: Leaders (. . .) indicate a nil or negligible amount. N.a. indicates "not applicable." Numbers in parentheses indicate implicit taxes.

[a]Financial and economic profitability of *boro* rice is calculated using the long-run trend market price as the price of *boro* rice.

[b]Irrigation is assumed to be provided by farmer-owned shallow tubewell (STW).

Table 18—Sources of differences between financial and economic profitability (SW Zone)

				Differences resulting from policies or market failures affecting				
Crop	Financial profitability[a] (1)	Economic profitability[a] (2)	Difference (3)	Producer prices (4)	Irrigation costs[b] (5)	Input prices (6)	Labor costs (7)	Other costs (8)
				(Tk/hectare)				
Irrigated crops								
Wheat	1,696	7,895	(6,199)	(5,720)	(49)	(354)	(57)	(19)
Boro rice	13,664	15,015	(1,350)	...	(506)	11	(804)	(51)
Rainfed crops								
Wheat	3,604	8,322	(4,718)	(4,407)	n.a.	(111)	(188)	(12)
Oilseeds	6,631	6,046	585	576	n.a.	62	(54)	0
Pulses	7,792	7,412	380	605	n.a.	(107)	(110)	(9)

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.

Notes: Leaders (. . .) indicate a nil or negligible amount. N.a. indicates "not applicable." Numbers in parentheses indicate implicit taxes.

[a]Financial and economic profitability of *boro* rice is calculated using the long-run trend market price as the price of *boro* rice.

[b]Irrigation is assumed to be provided by farmer-owned shallow tubewell (STW).

Table 19—Sources of differences between financial and economic profitability (NE Zone)

				Differences resulting from policies or market failures affecting				
Crop	Financial profitability[a] (1)	Economic profitability[a] (2)	Difference (3)	Producer prices (4)	Irrigation costs[b] (5)	Input prices (6)	Labor costs (7)	Other costs (8)
				(Tk/hectare)				
Irrigated crops								
Wheat	...	...	...	...	...	...	...	...
Boro rice	3,515	4,591	(1,077)	...	0	(19)	(1,015)	(43)
Rainfed crops								
Wheat	1,835	6,625	(4,790)	(3,884)	n.a.	(861)	(8)	(36)
Oilseeds	17,979	13,542	4,438	4,368	n.a.	73	(5)	2
Pulses	...	...	...	...	n.a.	...	...	...

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.

Notes: Leaders (. . .) indicate a nil or negligible amount. N.a. indicates "not applicable." Numbers in parentheses indicate implicit taxes.

[a]Financial and economic profitability of *boro* rice is calculated using the long-run trend market price as the price of *boro* rice.

[b]Irrigation is assumed to be provided by farmer-owned shallow tubewell (STW).

separate effects of policies (and market failures) relating to producer prices, irrigation costs, purchased input prices, labor costs, and other costs.

Policies affecting producer prices have different effects on the various crops (column 4). For wheat, market prices received by farmers are considerably below economic prices, resulting in a large implicit tax on production. For *boro* rice, producer price policies have no effect because the long-term average market price is used for both financial and economic prices (under the assumption that the nation is basically self-sufficient in rice and that domestic markets are relatively undistorted). For oilseeds, market prices received by farmers are well above economic prices (import parity prices), resulting in a large implicit subsidy to production. For pulses, market prices exceed parity prices in some zones but not in others, indicating that market prices reflect localized supply and demand conditions and suggesting no consistent effect resulting from producer price policies.

Policies affecting irrigation include exchange rate policies (since overvaluation of the taka increases the cost of imported pumps and irrigation equipment), and, more important, the tax on diesel fuel. Overall, irrigation policies impose a modest tax on producers, at least on producers whose irrigation pumps are powered by diesel fuel (column 5). This represents a major change, compared with past years when irrigation was heavily subsidized through government provision of water at below-market rates.

Policies affecting the prices of purchased inputs include primarily the policies affecting the prices of seed, fertilizer, and pesticides (column 6). Implicit taxes on the prices of seeds and pesticides are partially offset by implicit subsidies to imported fertilizers. The net effect varies depending on the mix of inputs used, with producers who use large amounts of fertilizer usually paying a net implicit tax, and others receiving a net implicit subsidy. That policies affecting the prices of purchased inputs largely offset one another represents a major change from past years, when subsidies on fertilizers were much larger and generally dominated all other effects. However, even though the net taxation of farmers through input price policies appears to be negligible, the remaining distortions in the prices of individual inputs may contribute to their inefficient use.

Since labor markets are reasonably competitive, especially during periods of peak labor demand when most cropping operations take place, on the whole, distortions in labor markets do not greatly affect profitability (column 7). Crop production is implicitly taxed to a slight degree in the sense that wages paid during slack periods are higher than the marginal value product of labor. On the whole, however, this effect is negligible.

In sum, by far the main factors influencing the financial profitability of food crop production during *rabi* season are policies affecting the commodity prices received by farmers. For wheat and pulses, farmers are implicitly taxed because the prices they receive are below the prices that would presumably prevail in the absence of government policies and market distortions. In contrast, oilseed producers receive an implicit subsidy because oilseed prices are well above the import parity price. All other policies have a relatively minor effect on financial profitability, with the possible exception of the implicit tax on diesel fuel, which affects *boro* rice production the most because *boro* rice has such heavy irrigation requirements.

CHAPTER 6

Efficiency Measures

Although economic profitability provides one measure for assessing the relative efficiency of alternative cropping activities, comparing net returns per unit of land area is complicated by activities that may differ greatly in their input intensity. Therefore, the information used for the economic profitability analysis is used to calculate DRCs for the different crops. DRCs are unit-free ratios that express the efficiency of alternative production activities by indicating the total value of domestic resources required to generate or save a unit of foreign exchange.

Following Masters and Winter-Nelson (1995), the DRC formula can be derived from a general production function, such as

$$Q_o = f(Q_d, Q_t), \tag{2}$$

where $\partial Q_o / \partial Q_i \;\; 0$, and $\partial^2 Q_o / \partial Q_i^2 \;\; 0$;
for all, $i = d, t$.

In this formulation, output (Q_o) is a function of two composite inputs, nontradable domestic factors (Q_d) and tradable goods (Q_t), which is produced under a prevailing set of social opportunity costs (P_o, P_d, P_t). As before, one indicator that can be used to rank a series of activities in terms of their contribution to national income is economic profitability (Π):

$$\Pi(Q_o) = P_o Q_o - P_d Q_d - P_t Q_t. \tag{3}$$

However, since Π is denominated in terms of a specific numeraire (usually currency units per unit of land area), comparisons across activities can be problematic, and a unit-free measure is preferable.[32] The DRC ratio is derived from equation (2) by isolating the value of domestic resources used in the activity ($P_d Q_d$) and dividing both sides by value-added to tradables ($P_o Q_o - P_t Q_t$):

[32] Masters and Winter-Nelson (1995) express the left-hand side of equation (2) in terms of net social profits. The use of this term has been avoided here so as not to imply that the economic prices used in this analysis are adjusted to take into account social weighting factors.

$$P_d Q_d / (P_o Q_o - P_t Q_t) = 1 - \partial Q_o / (P_o Q_o - P_t Q_t). \qquad (4)$$

The left side of this equation is the DRC ratio, a unit-free measure that can be used to make comparisons of disparate activities along a single normalized scale.[33]

Krueger (1966), Bruno (1967), and other early practitioners of DRC analysis calculated DRCs without explicitly estimating a shadow exchange rate; they expressed economic (shadow) prices for domestic factors in local currency and economic (shadow) prices of tradables in foreign currency and ranked activities in terms of local currency costs per unit of foreign exchange earned or saved. This "relative DRC" had the advantage of avoiding possible errors resulting from incorrect calculation of the shadow exchange rate, but it could not be used to distinguish efficient from inefficient activities.

More recent DRC practitioners have routinely included calculation of a shadow exchange rate, which allows all costs to be converted into a common currency (for example, see Srinivasan and Bhagwati 1978; Scandizzo and Bruce 1980; Monke and Pearson 1989; and Tsakok 1990). The resulting "absolute DRC" gives the same rankings as the "relative DRC," but it has the additional advantage of incorporating the efficiency criterion. Interpretation of absolute DRCs is straightforward: efficient activities that contribute to national income have DRCs between 0 and 1, while inefficient activities that consume more domestic resources than they generate net value added to tradable goods and services have DRCs greater than 1. "Breakeven" activities have DRCs of exactly 1.[34]

The DRCs calculated for wheat and alternative crops are consistent with the results of the economic profitability analysis (Table 20).[35] In irrigated plots, *boro* rice production is most efficient in the NW, NC, and SW Zones; irrigated wheat production is most efficient in the SC Zone; and oilseed production is most efficient in the NE Zone.[36] In nonirrigated plots, where production of irrigated wheat and *boro* rice are not possible, wheat production represents the most efficient use of domestic resources in all zones except the NE Zone, where oilseeds once again dominate.

---

[33] Masters and Winter-Nelson (1995) argue that the generalized social cost-benefit ratio (SCB) constructed by isolating all of the costs in equation (2) on the left-hand side and dividing by revenue, that is, $SCB = (P_d Q_d + P_t Q_t) / P_o Q_o$, yields a more accurate ranking of social profitability than the DRC, which tends to favor activities that make intensive use of tradable inputs. While the potential distortions described by Masters and Winter-Nelson may be of concern when the activities being compared differ significantly in their relative use of domestic factors and tradable inputs, in this case the alternative cropping activities being compared are sufficiently similar in their use of the two categories of inputs that the DRC and SCB approaches yield identical profitability rankings.

[34] In a long-run general-equilibrium situation, characterized by a complete absence of price distortions, DRCs for all production alternatives by definition would equal 1. In practice, this situation is never observed because the long-run general-equilibrium situation never obtains. In this context, the DRC can be interpreted as a measure of the efficiency with which a given production activity generates value added.

[35] The results presented in Table 20 refer to the baseline scenario, in which rice is priced using an adjusted market price falling between the import and export parity prices.

[36] The extremely low DRC for rainfed oilseeds in the NE Zone indicates that it is more efficient to use potentially irrigable plots for this rainfed crop than for the production of irrigated rice or wheat.

Table 20—Domestic resource cost (DRC) ratios for *rabi* food crops

	Irrigated crops		Nonirrigated crops		
Zone	Wheat (1)	*Boro* rice (2)	Wheat (3)	Oilseeds (4)	Pulses (5)
NW	1.75	0.28	0.67	3.02	1.58
NC	1.53	0.68	0.81	1.27	2.13
SC	0.91	1.08	0.86	2.12	1.17
SW	1.64	0.68	0.92	1.30	1.09
NE	. . .	1.83	1.65	0.56	. . .

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.
Note: Leaders (. . .) indicate not applicable or a nil or negligible amount.

CHAPTER 7

Sensitivity Analysis

Sensitivity analysis is carried out to determine the degree to which the efficiency measures calculated under the set of baseline assumptions are likely to be affected by changes in the values of key parameters. Sensitivity analysis is warranted for two main reasons. First, the profitability analysis is based on certain simplifying assumptions regarding production technologies, input-output parameters, market conditions, financial prices, economic prices, government policies, and so forth. Since the values used for these parameters obviously affect the analysis, it is important to know the degree to which the empirical results are sensitive to the simplifying assumptions that were made. Second, the efficiency rankings produced by the DRC framework are static in the sense that they represent a snapshot taken at a fixed point in time, whereas actual efficiency rankings are dynamic in the sense that they can and do change in response to changes in resource endowments, production technology, market conditions, and government policies. Therefore, it is important to determine whether the results are likely to be affected by future changes in any of these key parameters.

Effect of Changes in Output Prices

In considering the effects of potential output price changes, it is important to distinguish between two distinct sources of change: changes in the method used to calculate the parity prices and changes in the international reference prices on which the parity price calculations are based.

Changes in the Method of Calculation

Many wheat-producing households in Bangladesh are net buyers of cereals during certain periods of the year, especially during the hungry season immediately preceding the start of the *boro* rice harvest (Chowdhury 1993b). During this period, wheat generally is not marketed; rather, it is retained for home consumption. Wheat that is consumed at home substitutes for wheat or other cereals that otherwise would have to be purchased and consequently has a higher value to the producer than wheat that is marketed.[37] Table 21 summarizes the results of the economic profitability analysis when wheat import parity prices reflecting home consumption are substituted for import parity prices reflecting sale on the Dhaka market. As expected, the higher value of wheat that is consumed at home increases the economic profitability of wheat relative to other crops, although generally not enough to affect the profitability rankings.

Changes in the International Reference Prices

Output price changes can also be caused by movements in the international reference prices on which parity price calculations are based. Movements in international reference prices for cereals are notoriously difficult to predict, reflecting as they do changes in global supply and demand conditions attributable to climatic variability, shifts in market structural conditions, and changes in the policies pursued by leading importers and exporters of cereals. Given the extreme unreliability of long-term price forecasts, in this study no attempt is made to carry out sensitivity analysis using projected long-term international reference prices. Instead, the size of the price changes needed to alter the current profitability rankings is calculated.

Table 22 shows the changes in economic prices for outputs that would be required in the NW Zone for the crop that currently ranks first in economic profitability to be displaced. An increase of 150 percent in the price of oilseeds and 52 percent in pulses and a 10 percent decrease in the price of wheat would be required for rainfed wheat to be displaced as the most profitable nonirrigated *rabi* crop in the NW Zone, according to the third row of Table 22. These results indicate that extremely large changes would be

Table 21—Effect on relative economic profitability of *rabi* food crops of a change in the wheat valuation method

	Irrigated crops			Nonirrigated crops			
	Wheat[a]		*Boro* rice[b]	Wheat[a]		Oilseeds[a]	Pulses[a]
Zone	Dhaka consumption	On-farm consumption	Dhaka consumption	Dhaka consumption	On-farm consumption	Dhaka consumption	Dhaka consumption
				(Tk/hectare)			
NW	8,450	11,230	17,664	7,911	10,465	1,043	3,866
NC	10,141	13,405	18,453	9,948	12,468	7,527	4,105
SC	12,736	16,911	11,227	7,285	9,480	2,852	5,958
SW	7,895	9,935	15,015	8,322	10,068	6,046	7,412
NE	. . .	. . .	4,591	6,625	8,185	13,542	. . .

Source: Calculated by the authors.
Note: Leaders (. . .) indicate a nil or negligible amount.
[a]Import parity price.
[b]Adjusted market price.

[37] For purchased wheat, the value at the farmgate includes transportation and handling costs from Dhaka, whereas for marketed wheat, transportation and handling costs to Dhaka must be absorbed by the producer.

Table 22—Output price changes needed to alter efficiency rankings in the NW Zone

Item	Irrigated crops		Nonirrigated crops		
	Wheat (1)	*Boro* rice (2)	Wheat (3)	Oilseeds (4)	Pulses (5)
Current economic price (Tk/kilogram)	8.17	5.52	8.17	13.16	15.08
Price required for this crop to rank first or drop out of first in profitability (Tk/kilogram)	12.96	3.87	7.35	32.89	22.9
Required increase or decrease (percent)	59	–30	–10	150	52

Source: Calculated by the authors.

required in the economic prices of pulses and oilseeds in order for the current efficiency rankings to be altered. But, the same cannot be said for the economic prices of wheat and rice. For example, a decline in wheat prices of 10 percent would lower the profitability of nonirrigated wheat below that of pulses. The profitability rankings in the other zones would be affected similarly. Price changes of these magnitudes have been experienced in international rice and wheat markets in recent years, so current patterns of comparative advantage could be affected by future changes in output prices.

Effect of Changes in Input Prices

Sensitivity analysis is carried out to determine whether the results obtained under the baseline assumptions are likely to change as the result of possible future changes in the prices of two major inputs, irrigation and labor.

Irrigation

Irrigation costs consist mainly of fixed capital costs associated with purchasing a pump and variable fuel costs associated with operating the pump. Of the two, the capital cost is relatively small, given the modest cost of small-scale STW pumps now being produced locally. On the other hand, the cost of the fuel required to run the pump is substantial, representing about 78 percent of the hourly operating cost of STWs powered by diesel fuel (not including the operator's wages). Since diesel fuel used for irrigation is a tradable good, the profitability of irrigated crops stands to be affected by possible changes in world petroleum prices. Table 23 shows how the DRCs of the five *rabi* crops are affected by changes in the price of diesel fuel.[38] (Results are presented only for the NW Zone; the effects will be similar across all zones.) The values in Table 23 were

[38] Although changes in the price of diesel fuel affect profitability mainly by influencing the variable cost of irrigation, it should be noted that changes in the price of diesel also influence the transport costs used in calculating parity prices for tradable commodities and fertilizers.

Table 23—Effect on domestic resource cost ratios of changes in the diesel fuel price (NW Zone)

	Irrigated Crops		Nonirrigated Crops		
Diesel fuel conversion factor[a]	Wheat	*Boro* rice	Wheat	Oilseeds	Pulses
1.05	1.71	0.64	0.88	3.03	1.15
0.95	1.73	0.63	0.88	3.03	1.15
0.85[b]	1.75	0.62	0.88	3.03	1.15
0.75	1.77	0.62	0.88	3.03	1.15
0.65	1.79	0.61	0.88	3.03	1.15

Source: Calculated by the authors.
[a]Factor used to convert from the financial price of diesel fuel to the economic price.
[b]Value used in baseline scenario to reflect the 15 percent tax on diesel fuel.

obtained by substituting into the economic budgets higher and lower values for the diesel conversion factor used to convert the market price of diesel fuel into the economic price. Changes in the conversion factor directly affect the economic price and thus reveal the effects of possible changes in world petroleum prices on the efficiency of each crop.

The results in Table 23 are unremarkable. As expected, increases in the price of diesel fuel (modeled by increasing the diesel conversion factor) increase the DRCs for all crops, while decreases in the price of diesel decrease the DRCs. The effect is significant in the case of the two irrigated crops, because irrigation requires considerable use of diesel; the effect on nonirrigated crops is negligible. For the irrigated crops, the elasticity of the profitability with respect to the price of diesel is fairly low; for example, a 12 percent increase in the price of diesel causes the DRC of irrigated wheat to rise by less than 1 percent and the DRC of irrigated *boro* rice to rise by less than 2 percent (*boro* rice is affected to a greater degree because of its much higher irrigation requirements).

Labor

Since many of the crop production technologies currently in use are fairly labor-intensive, the cost of labor is likely to have considerable influence on production efficiency. And since labor requirements vary considerably from crop to crop, the efficiency rankings are likely to be affected by changes in labor costs. Table 24 shows how the DRCs of the five *rabi* crops are affected by changes in the price of labor. (Results are presented only for the NW Zone; the effects will be similar across all zones.) The values in Table 24 are obtained by substituting into the economic budgets higher and lower values for the wage rate conversion factors used to convert market wage rates into shadow wage rates. Changes in the conversion factor directly affect the shadow wage rate and thus reveal the effects of possible changes in future labor supply and demand conditions on the efficiency of each crop. They also indicate the degree to which any possible error in estimating shadow wage rates is likely to affect the results of the DRC analysis.

The results presented in Table 24 suggest that the DRCs of the main *rabi* food crops are fairly sensitive to changes in shadow wage rates. As the wage rate conversion

Table 24—Effect on domestic resource cost ratios of changes in shadow wage rates (NW Zone)

Wage rate conversion factors		Irrigated		Nonirrigated		
Peak season	Slack season	Wheat	*Boro* rice	Wheat	Oilseeds	Pulses
0.50	0.50	1.82	0.59	0.85	3.20	1.20
0.75	0.50	1.79	0.61	0.86	3.11	1.18
0.75	0.75	1.77	0.61	0.85	3.10	1.19
1.00[a]	0.50[a]	1.75	0.62	0.88	3.02	1.15
1.00	0.75	1.73	0.63	0.87	3.01	1.17
1.00	1.00	1.71	0.64	0.85	3.00	1.18

Source: Calculated by the authors.
[a]Baseline scenario values (full employment during peak season, underemployment during slack season).

factors are decreased (effectively lowering shadow wage rates), DRCs increase for irrigated wheat and decrease for irrigated rice. The effect on DRCs of rainfed crops is less pronounced, which is unsurprising considering that production of rainfed crops requires less labor. On the whole, the efficiency rankings are unaffected.

Effect of Changes in the Shadow Exchange Rate

The shadow exchange rate used in calculating economic prices for tradables was varied in order to determine the degree to which any possible error in estimating the shadow exchange rate is likely to affect the results of the analysis.[39] Table 25 shows how the DRCs of the five *rabi* crops are affected by changes in the shadow exchange rate. (Results are presented only for the NW Zone; the effects will be similar across all zones.) In the case of wheat, increases in the exchange rate adjustment factor (representing a strengthening of the taka relative to the U.S. dollar) decrease production efficiency, because the decrease in gross revenues caused by a fall in the import parity price of wheat exceeds the cost savings achieved as a result of falling prices of imported inputs. In the

Table 25—Effect on domestic resource cost ratios of changes in the exchange rate (NW Zone)

	Irrigated		Nonirrigated		
Exchange rate adjustment factor[a]	Wheat	*Boro* rice	Wheat	Oilseeds	Pulses
1.05	2.24	0.51	0.88	2.95	1.15
0.95	1.99	0.56	0.88	2.99	1.15
0.85[a]	1.75	0.62	0.88	3.02	1.15
0.75	1.51	0.70	0.87	3.06	1.16
0.65	1.28	0.81	0.87	3.10	1.16

Source: Calculated by the authors.
[a]Value used in baseline scenario to reflect estimated 15 percent overvaluation of the taka.

[39] Only direct exchange rate effects were considered; that is, changes to directly calculated parity prices. No attempt was made to adjust the standard conversion factor.

case of rice, increases in the exchange rate adjustment factor have the opposite effect: production efficiency rises because gross revenues remain unaffected (since the economic price of rice has been set equal to the long-run trend domestic market price) while prices of imported inputs fall. In the case of oilseeds and pulses, increases in the exchange rate adjustment factor similarly increase production efficiency, although only slightly.

The results presented in Table 25 suggest that profitability levels are moderately sensitive to changes in the shadow exchange rate, particularly for irrigated crops. However, even the relatively large changes in the exchange rate tested as part of the sensitivity analysis fail to affect the efficiency rankings, presumably because the cost structures of the five crops are relatively similar. The largest relative change occurs between rice and the other four crops, but because *boro* rice production enjoys a large efficiency advantage (at least in the NW Zone), even relatively large changes in the shadow exchange rate fail to dislodge it from its position as most efficient.

One caveat must be made concerning the results of the sensitivity analysis involving the shadow exchange rate. In this study, gross revenues to *boro* rice production are unaffected by changes in the exchange rate because of the assumption that the domestic market-clearing equilibrium price for rice falls between the import parity and export parity prices, making trade unprofitable. However, since changes in the exchange rate directly affect the parity prices, the taka-denominated price band demarcated by the import and export parity prices will shift up or down with changes in the exchange rate. If the band shifts far enough in either direction, eventually trade will become profitable again (with the direction of trade determined by the movement of the band). Should this happen and should trade in rice resume, then the economic price of rice would once again correspond to the parity price, which would mean that gross revenues to rice production would be directly affected by the exchange rate. This possibility is not explored here.

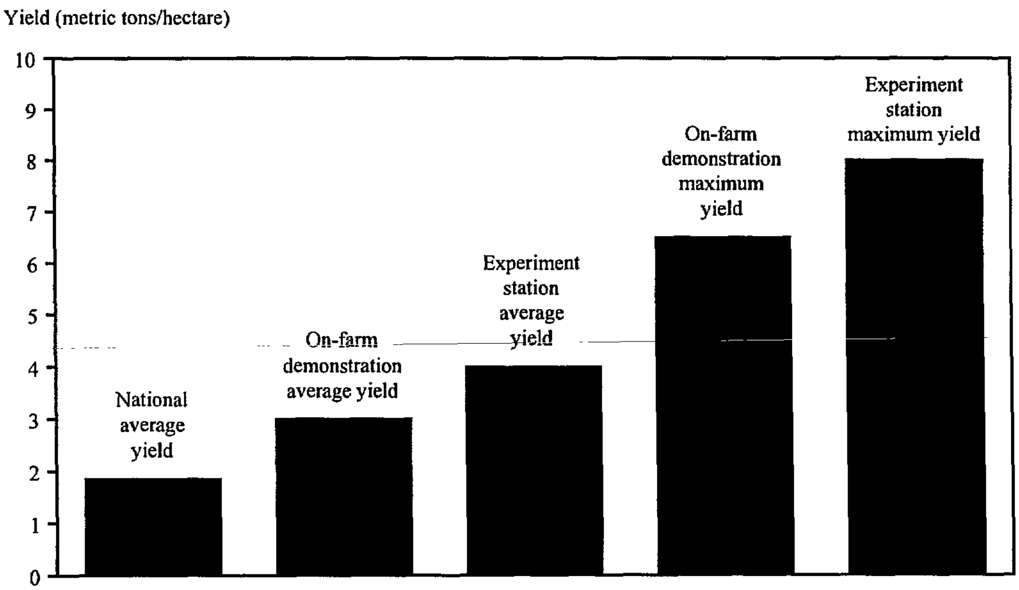
Effect of Possible Future Changes in Wheat Production Technology

Future efficiency rankings could be altered by technological changes affecting the cost of production of wheat relative to other crops. For example, if adoption of improved management practices for wheat succeeds in significantly reducing the cost of wheat production, the efficiency of wheat production relative to production of alternative crops might increase sufficiently for wheat to displace other more efficient alternatives. Experimental results from the Wheat Research Centre in Dinajpur (supported by the results of trials carried out at other regional research stations) suggest that wheat yields in farmers' fields could be raised considerably using currently available technologies. The most promising of these involve changes in the level of use of purchased inputs, such as seed and fertilizer, as well as changes in management practices such as land preparation, planting date, and irrigation management. Currently, the so-called "yield gap" for wheat (which measures the difference between experimental yields and farmers' actual yields) is quite large. Wheat yields achieved in experiment station trials using recommended management practices average around 4 tons per hectare, approximately 33 percent higher than the average yields achieved in controlled on-farm demonstrations and more than double the average level actually achieved by farmers (Figure 12). Although yield gap comparisons between crops are complicated by differences in crop genetic potential and input use requirements, the yield gap in wheat is much larger in absolute and percentage terms than the equivalent yield gap in rice, according to the director of the Wheat Research Centre in Dinajpur, M. A. Razzaque.[40]

The effect of possible future changes in wheat production technology is modeled by increasing the yields of wheat in the budgets, holding input costs constant. The degree to which wheat yields would have to increase (at current levels of input costs) in order for wheat to displace other currently more efficient crops is shown in Table 26. In zones where wheat currently trails one or more other crops, the required yield increases appear large, ranging from 20 to 60 percent. Nevertheless, yield gains of this magnitude are not unattainable, and in fact the yields required to alter the current rankings (3 tons per hectare for irrigated wheat and 2 tons per hectare for rainfed wheat) are already being achieved by some progressive farmers. It is important to remember, however, that in order for wheat to displace other crops, the yield gains assumed in Table 26 would have to be achieved at current levels of input costs, whereas the high yields achieved by progressive farmers are often achieved with the help of high levels of inputs.

Whether adoption of improved technology will increase the efficiency of wheat production is of course difficult to predict. However, the existence of a large yield gap for wheat suggests that significant productivity gains could potentially be realized in the short- to medium-term through adoption of technology that is already "on the shelf."

Figure 12—Wheat yield gap, early 1990s



Source: Bangladesh Wheat Research Centre, Dinajpur.

[40] M. A. Razzaque, director of the Wheat Research Centre, personal communication, July 1993.

Table 26—Changes in wheat yields needed to alter efficiency rankings

Item	Zone				
	NW	NC	SC	SW	NE
Irrigated wheat					
Current yield (tons/hectare)	1,927	2,211	2,651	1,846	. . .
Yield required for irrigated wheat to rank first in economic profitability (tons/hectare)	3,075	3,250	2,651	2,700	. . .
Required increase (percent)	60	47	0	46	. . .
Nonirrigated wheat					
Current yield (tons/hectare)	1,769	1,707	1,393	1,581	1,636
Yield required for rainfed wheat to rank first in economic profitability (tons/hectare)	1,769	1,707	1,890	1,900	2,475
Required increase (percent)	0	0	36	20	51

Source: Calculated by the authors.
Note: Leaders (. . .) indicate a nil or negligible amount.

The situation is quite different from that of *boro* rice, where the yield gap is much smaller. This indicates that *boro* rice farmers have already captured the potential benefits of existing technology and that yield gains are much less likely to be realized in the short to medium run.

CHAPTER 8

Conclusions and Policy Implications

In the years since Bangladesh achieved independence in 1971, the nation's agricultural sector has undergone a remarkable transformation. With the help of sustained government investment in irrigation infrastructure, input delivery systems, research facilities, and extension services, farmers have achieved a dramatic increase in cereal production. Defying the predictions of many analysts, Bangladesh has transformed itself from perennial food importer to its current position at or near self-sufficiency in rice, the major staple. Production of wheat, the second most important cereal, also has increased significantly, although the nation remains a net importer of wheat.

Having achieved one important medium-term goal, Bangladeshi policymakers must now decide on a strategy for the longer term. One option would be to continue to promote rice production for eventual export by maintaining existing policies that subsidize the cost of irrigation, stabilize rice output markets, and ensure a high level of public-sector investment in rice research. Another option would be to attempt to stabilize rice production at approximately the rate of population growth while encouraging producers to diversify into alternative crops. Given existing resource constraints (especially the lack of uncultivated land onto which to expand production), it will be hard to pursue both strategies simultaneously, so difficult choices will have to be made.

One critical issue concerns the future role of wheat. Despite the impressive gains in wheat production realized during the past two decades, supplies of wheat continue to fall well short of demand, and the nation must rely on imports to meet domestic consumption requirements. Some policymakers have argued that with the national rice deficit now largely overcome, the time has come to invest additional resources in wheat research and production support activities. Others have pointed out that such a strategy would not be cost-effective, especially since increased wheat production can come only at the expense of production of competing crops, including rice.

The results presented in this report support one important finding of the earlier studies: in most irrigated areas, *boro* rice generates greater financial net returns to farmers' labor and management and to land than competing crops. Although the profitability of *boro* rice production is declining now that Bangladesh is close to achieving self-sufficiency in rice and domestic market prices for rice are falling, *boro* rice remains the most profitable option for farmers, at least in areas where its production is technically feasible.

While this conclusion supports what many policymakers have been saying about the inability of wheat to compete head-to-head with *boro* rice, three additional findings cast doubt on the widely held view that the long-term prospects for wheat are poor:

1. Where conditions are not right for growing rice, wheat is often highly competitive. Although *boro* rice tends to be more profitable in financial terms, it cannot be grown where irrigation services are not available. *Boro* rice is grown predominantly in heavy soils located in low-lying irrigated areas. In elevated areas with light-textured soils, in nonirrigated zones, and in places where irrigation is especially expensive, wheat is a better crop choice.
2. Wheat production can use domestic resources efficiently. When inputs and outputs are assigned economic prices representing their scarcity value, the relative profitability of wheat increases considerably. Under economic pricing, wheat currently dominates on most nonirrigated land, and in one zone it is competitive with *boro* rice even on irrigated land. Should Bangladesh become a consistent rice exporter, the economic case for wheat would become even stronger.
3. Many rural households grow wheat to ensure adequate household food supplies during the hungry season prior to the *boro* rice harvest. For households that lack the resources to purchase food during the hungry season, the decision to grow wheat is driven by the desire to avoid seasonal food shortages.

These findings have several implications for policy. First and foremost, they make clear that wheat production has a legitimate place in the Bangladeshi cropping pattern, both for reasons of economic efficiency and as a diversification measure designed to increase household food security. Price distortions that discriminate against wheat should therefore be avoided. Moreover, when formulating policies for agricultural development, the government of Bangladesh should investigate the costs and benefits of supporting wheat along with other crops.

How can Bangladesh exploit its opportunities for efficient wheat production? Although further analysis will be needed to assess on a case-by-case basis the likely effects of alternative policy reforms (taking into account the full range of welfare effects not only on producers but also on consumers), certain measures seem desirable. Recent steps taken to reform delivery systems for inputs seem to have succeeded in improving the performance of input markets and reducing distortions on input prices, so the prospective gains from further reforms to input markets are likely to be modest. However, producer prices for wheat remain considerably below import parity levels, possibly as the result of continuing high levels of food aid and subsidized commercial imports. Since low prices undermine financial incentives to grow wheat, increased production could be promoted through the introduction of measures designed to remove the policy distortions that are currently penalizing wheat producers. Based on past experience, efforts to support farmgate prices directly (procuring wheat at a support price, for example) are likely to prove excessively costly. More effective approaches might be to restrict imports of food aid or to target food aid more carefully in order to generate upward pressure on producer prices. The resulting increase in domestic wheat production would reduce dependence on politically undesirable imports, albeit at some cost to consumers, since domestic wheat would substitute for low-cost imports. Also, at present a significant portion of imported wheat food aid is distributed to the poor, so steps would have to be taken to ensure that the poor still have adequate access to food. Another possibility would be to request that food aid donors replace wheat with rice or other cereals or monetize food aid programs (for a discussion of these options, see Dorosh and Haggblade 1996).

Meanwhile, the recent calls to reduce support to wheat research must be questioned. Although much more rigorous analysis will be needed to define appropriate wheat research priorities, some reorientation of current research efforts seems warranted. Since wheat is particularly competitive in areas where irrigation is either absent or unreliable, researchers will have to concentrate additional attention on technologies suited for rainfed conditions. Currently there is a clear need for wheat varieties that tolerate heat and drought stress and that yield well under conditions of reduced fertility (since farmers are unlikely to apply high levels of fertilizer in production environments characterized by low and uncertain rainfall). Similarly, farmers require training in crop management practices appropriate for rainfed conditions, especially technologies designed to conserve soil moisture.

In irrigated production environments, the challenge facing researchers is a bit different. Since wheat frequently will not be able to compete with *boro* rice in areas suited to *boro* rice production (except in the SC Zone), the first step will be to define those areas clearly. The producer survey carried out as part of this study generated evidence that farmers plant *boro* rice and wheat in different plots, but the decisionmaking process driving the selection of plots is still poorly understood. Additional research is needed to shed light on the interactions among the key micro-level factors that determine whether a given plot is suitable for *boro* rice. This is likely to require farm-level surveys involving extensive soil sampling and analysis. Also, it would be particularly useful to determine the break-even yield levels for wheat and *boro* rice (for different zones and under alternative production technologies) —the point where *boro* rice loses its profitability advantage. Only when the factors determining the relative performance of the two crops are better understood will it be possible to identify research priorities for irrigated wheat.

Finally, there is a need to improve the process by which improved wheat production technologies are transferred to farmers. The large yield gap for wheat suggests that there is still considerable room for raising yields at the farm level using currently available technologies. Although the low yields observed in farmers' fields may be attributed to a lack of incentive to invest in inputs (due to depressed wheat prices) and to resource constraints experienced by those who grow wheat (particularly if wheat is grown disproportionally by poorer households), crop management practices for wheat are clearly deficient in many areas. Yields undoubtedly could be improved by the effective transfer of technologies already "on the shelf."

To what extent do these results from Bangladesh have wider implications? Many other developing countries currently undergoing agricultural intensification are also experiencing an uneven pattern of productivity growth. In Bangladesh, the dramatic productivity gains achieved in rice have not been matched in other cereals. Maintaining productivity growth across the entire agricultural sector during the post-Green Revolution period will depend on increasing productivity among secondary crops and "niche" commodities that exploit specific locational and seasonal advantages. Economic analyses conducted at a high level of aggregation will often miss these potential sources of growth and conclude that prospects are limited for further productivity gains in agriculture. This study of wheat in Bangladesh illustrates that seasonal and locational details matter, and it shows how policy analysis carried out at an appropriate level of disaggregation can help in identifying efficient production activities.

APPENDIX 1

Data Collection Activities

The results presented in this report differ from those presented in two earlier studies (the World Bank study and the BIDS-IFPRI study) in that they are based on detailed plot-level data collected for the specific purpose of comparing the profitability of wheat versus alternative crops in a number of distinct wheat production zones. The earlier studies used more generalized data sets collected for multiple purposes and consequently did not allow profitability to be examined on a disaggregated, zone-by-zone basis. Also, some of the technical parameters and price coefficients used in the earlier studies were collected from extremely limited samples.

Wheat Producer Survey

Design and implementation of the producer survey were influenced by four factors: (1) the need to capture the variability in wheat production technologies in different agroclimatic zones of Bangladesh; (2) a desire to include both wheat growers and nonwheat growers; (3) statistical theory; and (4) availability of resources. Information compiled from secondary sources, including official production statistics, national census data, agroclimatic zoning reports, and land suitability classifications, as well as census data compiled for a number of chosen villages were used to select a four-stage, clustered, stratified, purposive sample. The first stage of the sampling procedure was designed to distribute the sampling units across the entire range of wheat production environments found in Bangladesh. The second stage was designed to select 21 *thana*s, each of which had to contain at least some wheat growers.[41] The third stage was designed to select one village within each of the 21 chosen *thanas*. And the fourth stage was designed to select 20 farm households in each of the 21 chosen villages in a manner that would ensure inclusion not only of wheat-growing households, but also of households that do not grow wheat.

Farm households located in wheat-growing areas of Bangladesh formed the population from which units were drawn. At the outset of the survey, it was determined that sufficient resources were available to permit approximately 420 sets of interviews. For

[41] A *thana* is a subdistrict level unit ranging in size from 200 to 250 square kilometers and including about 100 villages.

logistical reasons (mainly to economize on transportation costs), it was decided that the respondents should be clustered. The 420 respondents were therefore divided into 21 clusters of 20 each, so that 20 sets of interviews could be scheduled in each of 21 villages.

In the first stage of the sampling procedure, the 64 districts of Bangladesh were classified into five broad agroclimatic categories defined in terms of land elevation (high, medium, and low) and suitability for wheat production (highly suitable, suitable, and unsuitable).

In the second stage of the sampling procedure—selection of 21 *thanas*—the 21 *thanas* were distributed among the five agroclimatic categories in proportion to the number of farm households located in each category in order to ensure that the five zones would be represented in proportion to their importance. However, since wheat is not grown everywhere in Bangladesh, it was necessary to introduce a purposive element into the *thana* selection procedure to ensure that at least some wheat growers could be found in all of the *thanas*. Therefore, for each *thana* to be selected, three slates containing five *thanas* each were chosen at random from within the relevant agroclimatic category. Knowledgeable wheat scientists were then asked to pick one of the three slates, the idea being to eliminate the two slates where relatively little wheat production could be expected. One *thana* was then selected randomly from the remaining slate.

In the third stage, one village was selected randomly within each of the 21 selected *thanas* by drawing one name from among the list of villages located in each *thana*. In three cases, the village selected initially was rejected on the grounds that no wheat growers could be found in the village and another village was selected randomly.

In the fourth stage, where 20 farm households were selected within each of the 21 selected villages, a census was conducted in each village to develop a list of all of the farm households in the village. The households were then classified into two groups: wheat-growing households and nonwheat-growing households. In order to ensure inclusion of both types, the sample was prestratified: in each village, 16 names were selected randomly from the list of wheat-growing households, and 4 names were selected randomly from the list of nonwheat-growing households. Because of miscommunication between two teams of enumerators, one extra wheat-growing household was interviewed in Baniachang Village, Hobiganj District, NE Zone. For this reason, the final sample size numbered 421, one more than the planned 420.

The purpose of the nonrandom sampling procedure was to ensure that all types of wheat producers (as well as some producers who do not grow wheat) would be represented in the final sample in sufficiently large numbers to ensure that separate budgets could be constructed for irrigated and nonirrigated wheat in each zone. The nonrandom sampling procedure had two limitations, however.

First, because the sample included a disproportionally large percentage of wheat-growing households, the results of the survey could not be used directly to draw inferences about the entire rural population of Bangladesh. Additional information obtained from a recent national agricultural census was introduced to allow adjustment of the survey results.

Second, because wheat growers and nonwheat growers were forced into the sample in fixed proportions (through prestratification), the sample included no locational variability in the incidence of wheat growing. Consequently, district- or village-level dummy variables could not be included in the logit analysis.

Because an important objective of the study was to include sufficient numbers of wheat-growing households to allow identification of wheat production zones and to enable construction of budgets for different categories of wheat producers, these limitations were considered acceptable.

Since a large amount of data was being sought, the producer survey proceeded in two stages. An initial round of interviews was conducted in March and April 1993. A team comprising seven enumerators and one supervisor spent an average of three days in each village to complete the 20 scheduled interviews. Because of the time required to travel to survey villages (many of which were located in remote areas), because of the difficulty experienced in locating and interviewing household heads, and because of the time needed to accompany respondents to their farms to collect soil samples, the team proceeded at the relatively slow rate of one interview per enumerator per day. The initial questionnaire focused on farm characteristics and cropping patterns.

A second round of interviews was conducted in May and June 1993. The follow-up questionnaire focused on cropping operations for wheat and alternative crops. All 420 farmers interviewed during the initial round were successfully contacted for follow-up interviews.

Other Primary Data Collection Activities

While the producer survey was under way, the supervisor of enumerators collected village-level data on rainfall, soil types, and infrastructure. In addition, in 18 out of the 21 survey villages, the supervisor visited two or three randomly selected irrigated farms and completed a short questionnaire focusing on the costs involved in purchasing, installing, and operating a shallow tubewell. Data were collected for a total of 52 tubewells for use in developing capital budgets for small-scale irrigation facilities.

APPENDIX 2

Supplementary Tables

Table 27—Import parity price for wheat, by zone, 1993

Commodity (No. 1 soft white winter wheat)	Zone				
	NW	NC	SC	SW	NE
			(US$/ton)		
F.o.b. Vancouver	126	126	126	126	126
plus ocean freight and insurance	40	40	40	40	40
C.i.f. Chittagong	166	166	166	166	166
			(Tk/ton)		
C.i.f. Chittagong[a]	7,616	7,616	7,616	7,616	7,616
plus port charges[b]	424	424	424	424	424
plus handling charges[c]	323	323	323	323	323
Landed cost, Chittagong	8,405	8,405	8,405	8,405	8,405
plus transport and handling costs[d]	485	485	485	485	485
Landed cost, Dhaka	8,890	8,890	8,890	8,890	8,890
minus assembly costs[e]	722	738	788	553	477
Farmgate price	8,169	8,152	8,103	8,338	8,414

Source: Calculated by the authors.
Note: All tons are metric tons.
[a]Converted using the shadow exchange rate.
[b]Port charges include unloading fees, labor, and bags.
[c]Handling fees include bank interest, letter of credit fee, and the clearing and forwarding fee.
[d]Transport costs include transport and handling from the port of Chittagong to the Dhaka wholesale market.
[e]Assembly costs include assembler operating costs, diesel fuel, food, salaries, transport, collection costs, bank interest, materials, and marketing margin.

Table 28—Import parity price for rice, by zone, 1993

Commodity (Thai milled white rice, 15 percent broken)	Zone NW	NC	SC	SW	NE
			(US$/ton)		
F.o.b. Bangkok	250	250	250	250	250
plus ocean freight and insurance	20	20	20	20	20
			(Tk/ton)		
C.i.f Chittagong	270	270	270	270	270
C.i.f Chittagong[a]	12,388	12,388	12,388	12,388	12,388
plus port charges[b]	192	192	192	192	192
plus handling fees[c]	601	601	601	601	601
Landed cost, Chittagong	13,181	13,181	13,181	13,181	13,181
plus transport costs[d]	485	485	485	485	485
Landed cost, Dhaka	13,666	13,666	13,666	13,666	13,666
minus processing costs[e]	895	895	895	895	895
minus assembly costs[f]	358	247	302	296	221
Farmgate price (rice)	12,413	12,524	12,469	12,475	12,550
Farmgate price (paddy)[g]	8,192	8,266	8,230	8,233	8,283

Source: Calculated by the authors.
[a]Converted using the shadow exchange rate.
[b]Port charges include unloading fees, labor, and bags.
[c]Handling fees include bank interest, letter of credit fee, and the clearing and forwarding fee.
[d]Transport costs include transport and handling from the port of Chittagong to the Dhaka wholesale market.
[e]Processing costs include depreciation, electricity, labor, storage, operating costs, bank interest, rent, and margin.
[f]Assembly costs include assembler operating costs, diesel fuel, food, salaries, transport, collection costs, bank interest, materials, and marketing margin.
[g]Paddy: milled rice conversion ratio = 0.66.

Table 29—Export parity price for rice, by zone, 1993

Commodity (Bangladesh rice, parboiled)	Zone NW	NC	SC	SW	NE
			(US$/ton)		
F.o.b. Chittagong	190	190	190	190	190
			(Tk/ton)		
Chittagong[a]	8,717	8,717	8,717	8,717	8,717
minus port charges[b]	192	192	192	192	192
minus handling fees[c]	601	601	601	601	601
minus transport costs[d]	485	485	485	485	485
Wholesale price, Dhaka	7,439	7,439	7,439	7,439	7,439
minus processing costs[e]	895	895	895	895	895
minus assembly costs[f]	358	247	302	296	221
Farmgate price (rice)	6,186	6,297	6,242	6,248	6,323
Farmgate price (paddy)[g]	4,083	4,156	4,120	4,124	4,173

Source: Calculated by the authors.
[a]Converted using the shadow exchange rate.
[b]Port charges include unloading fees, labor, and bags.
[c]Handling fees include bank interest, letter of credit fee, and the clearing and forwarding fee.
[d]Transport costs include transport and handling from the port of Chittagong to the Dhaka wholesale market.
[e]Processing costs include depreciation, electricity, labor, storage, operating costs, bank interest, rent, and margin.
[f]Assembly costs include assembler operating costs, diesel fuel, food, salaries, transport, collection costs, bank interest, materials, and marketing margin.
[g]Paddy: milled rice conversion ratio = 0.66.

Table 30—Import parity price for oilseeds, by zone, 1993

Commodity (rapeseed)	Zone NW	NC	SC	SW	NE
			(US$/ton)		
F.o.b. Europe	245	245	245	245	245
plus ocean freight and insurance	20	20	20	20	20
C.i.f. Chittagong	265	265	265	265	265
			(Tk/ton)		
C.i.f. Chittagong[a]	12,159	12,159	12,159	12,159	12,159
plus port charges[b]	431	431	431	431	431
plus handling fees[c]	801	801	801	801	801
Landed cost, Chittagong	13,390	13,390	13,390	13,390	13,390
plus transport costs[d]	485	485	485	485	485
Landed cost, Dhaka	13,875	13,875	13,875	13,875	13,875
minus assembly costs[e]	715	624	684	614	609
Farmgate price	13,160	13,251	13,190	13,261	13,266

Source: Calculated by the authors.
[a]Converted using the shadow exchange rate.
[b]Port charges include unloading fees, labor, and bags.
[c]Handling fees include bank interest, letter of credit fee, and the clearing and forwarding fee.
[d]Transport costs include transport and handling from the port of Chittagong to the Dhaka wholesale market.
[e]Assembly costs include assembler operating costs, diesel fuel, food, salaries, transport, collection costs, bank interest, materials, and marketing margin.

Table 31—Import parity price for pulses, by zone, 1993

Commodity (red lentils)	Zone NW	NC	SC	SW	NE
			(US$/ton)		
F.o.b. Europe	420	420	420	420	420
plus ocean freight and insurance	20	20	20	20	20
C.i.f. Chittagong	440	440	440	440	440
			(Tk/ton)		
C.i.f. Chittagong[a]	20,188	20,188	20,188	20,188	20,188
plus port charges[b]	131	131	131	131	131
plus handling fees[c]	1,329	1,329	1,329	1,329	1,329
Landed cost, Chittagong	21,648	21,648	21,648	21,648	21,648
plus transport costs[d]	485	485	485	485	485
Landed cost, Dhaka	22,133	22,133	22,133	22,133	22,133
minus processing costs[e]	1,250	1,250	1,250	1,250	1,250
minus assembly costs[f]	774	679	739	669	652
Farmgate price (gross)	20,109	20,203	20,143	20,214	20,231
Farmgate price (net)[g]	15,082	15,153	15,108	15,161	15,173

Source: Calculated by the authors.
[a]Converted using the shadow exchange rate.
[b]Port charges include unloading fees, labor, and bags.
[c]Handling fees include bank interest, letter of credit fee, and the clearing and forwarding fee.
[d]Transport costs include transport and handling from the port of Chittagong to the Dhaka wholesale market.
[e]Processing costs include depreciation, electricity, labor, storage, operating costs, bank interest, rent, and margin.
[f]Assembly costs include assembler operating costs, diesel fuel, food, salaries, transport, collection costs, bank interest, materials, and marketing margin.
[g]Processing conversion ratio = 0.75

Table 32—Import parity price for triple superphosphate (TSP), by zone, 1993

Fertilizer (triple superphosphate [TSP])	Zone NW	NC	SC	SW	NE
			(US$/ton)		
F.o.b. Europe	121	121	121	121	121
plus ocean freight and insurance	30	30	30	30	30
C.i.f. Chittagong	151	151	151	151	151
			(Tk/ton)		
C.i.f. Chittagong[a]	6,905	6,905	6,905	6,905	6,905
plus port charges[b]	576	576	576	576	576
plus handling fees[c]	226	226	226	226	226
Landed cost, Chittagong	7,707	7,707	7,707	7,707	7,707
plus transport costs[d]	405	405	405	405	405
Landed cost, Dhaka	8,112	8,112	8,112	8,112	8,112
plus distribution costs[e]	764	604	664	594	698
Farmgate price	8,876	8,716	8,776	8,706	8,810

Source: Calculated by the authors.
[a]Converted using the shadow exchange rate.
[b]Port charges include unloading fees, labor, and bags.
[c]Handling fees include bank interest, letter of credit fee, and the clearing and forwarding fee.
[d]Transport costs include transport and handling from the port of Chittagong to the Dhaka wholesale market.
[e]Distribution costs include diesel fuel, food, salaries, transport depreciation, overhead, and wholesale and retail margins.

Table 33—Import parity price for muriate of potash (MP), by zone, 1993

	Zone				
Fertilizer (muriate of potash [MP])	NW	NC	SC	SW	NE
			(US$/ton)		
F.o.b. Europe	109	109	109	109	109
plus ocean freight and insurance	30	30	30	30	30
C.i.f. Chittagong	139	139	139	139	139
			(Tk/ton)		
C.i.f. Chittagong[a]	6,378	6,378	6,378	6,378	6,378
plus port charges[b]	488	488	488	488	488
plus handling fees[c]	213	213	213	213	213
Landed cost, Chittagong	7,078	7,078	7,078	7,078	7,078
plus transport costs[d]	405	405	405	405	405
Landed cost, Dhaka	7,483	7,483	7,483	7,483	7,483
plus distribution costs[e]	654	494	554	484	588
Farmgate price	8,137	7,978	8,038	7,967	8,071

Source: Calculated by the authors.
[a]Converted using the shadow exchange rate.
[b]Port charges include unloading fees, labor, and bags.
[c]Handling fees include bank interest, letter of credit fee, and the clearing and forwarding fee.
[d]Transport costs include transport and handling from the port of Chittagong to the Dhaka wholesale market.
[e]Distribution costs include diesel fuel, food, salaries, transport depreciation, overhead, and wholesale and retail margins.

Table 34— Capital budgets: Technical coefficients

Item	Shallow tubewell	Deep tubewell	Power tiller	Bullock team
Manufacturer	Dong Feng	Lister	Dong Feng	. . .
Horse power	12	40	12	. . .
Purchase price (Tk)	11,500	457,000	44,000	30,000
Salvage value coefficient	0.20	0.20	0.20	0.25
Salvage value (Tk)	2,300	91,400	8,800	7,500
Useful life (hours)	3,000	11,000	5,000	10,500
Annual use (hours)	1,000	1,100	1,000	1,000
Annual repairs cost coefficient	0.10	0.10	0.10	. . .
Hourly diesel consumption (liters)	1.00	3.80	1.50	. . .
Price of diesel (Tk/liter)	14.00	14.00	14.00	. . .
Hourly lubricant consumption (liters)	0.02	0.50	0.05	. . .
Price of lubricant (Tk/liter)	36.50	36.50	36.50	. . .
Annual feeding cost (Tk)	. . .	. . .	. . .	500.00
Annual veterinary expenses (Tk)	. . .	. . .	. . .	500.00
Operator's wages (Tk)	4.00	8.00	5.00	3.00
Cost of capital (percent)	15	15	15	15
Hourly operating costs (Tk)				
Depreciation	3.07	33.24	7.04	2.14
Repairs and maintenance	0.46	16.62	1.76	0.00
Fuel and lubricants/feeding	14.55	71.45	22.83	0.50
Operator's wages	4.00	8.00	5.00	3.00
Cost of capital	0.69	24.93	2.64	1.69
Total	22.76	154.23	39.27	7.33

Source: CIMMYT-IFPRI producer survey, 1993.
Note: Leaders (. . .) indicate not applicable.

Table 35—Comparison of selected financial and economic prices (NW Zone)

Item	Financial price	Economic price	Financial-economic price ratio
		(Tk/kilogram)	
Outputs			
Grain			
Irrigated wheat	4.96	8.17	0.61
Nonirrigated wheat	5.00	8.17	0.61
Rice (paddy)	5.52	5.52	1.00
Oilseeds	16.08	13.16	1.22
Pulses	13.91	15.08	0.92
By-products			
Irrigated wheat	0.44	0.44	1.00
Nonirrigated wheat	0.31	0.31	1.00
Rice (paddy)	0.25	0.25	1.00
Oilseeds	0.34	0.34	1.00
Pulses	0.69	0.69	1.00
Inputs			
Seed			
Irrigated wheat (own seed)	6.20	5.27	1.18
Nonirrigated wheat (own seed)	6.25	5.31	1.18
Rice (own seed)	5.79	4.92	1.18
Oilseeds (own seed)	20.10	17.09	1.18
Pulses (own seed)	17.39	14.78	1.18
Fertilizer			
Urea	6.15	6.15	1.00
Triple superphosphate (TSP)	8.00	8.88	0.90
Muriate of potash (MP)	6.50	8.14	0.80
Pesticide			
Irrigated wheat	267.61	238.17	1.12
Nonirrigated wheat	135.79	120.85	1.12
Boro rice	87.30	77.70	1.12
Diesel fuel (Tk/liter)	14.00	11.90	1.18
Labor		(Tk/day)	
Family labor			
Peak season	20.00	20.00	1.00
Slack season	20.00	10.00	2.00
Attached farm labor			
Peak season	19.85	19.85	1.00
Slack season	19.85	9.93	2.00
Casual labor			
Land preparation and broadcasting	32.05	32.05	1.00
Transplanting	25.61	25.61	1.00
Weeding	24.67	12.34	2.00
Harvesting and postharvest	27.99	27.99	1.00
All other activities	27.58	13.79	2.00

Sources: Financial prices collected through wheat producer survey. Economic prices calculated based on procedures explained in text.

Table 36—Comparison of selected financial and economic prices (NC Zone)

Item	Financial price	Economic price	Financial-economic price ratio
		(Tk/kilogram)	
Outputs			
Grain			
Irrigated wheat	5.32	8.15	0.65
Nonirrigated wheat	5.36	8.15	0.66
Rice (paddy)	5.92	5.92	1.00
Oilseeds	15.73	13.25	1.19
Pulses	15.10	15.15	1.00
By-products			
Irrigated wheat	0.50	0.50	1.00
Nonirrigated wheat	0.48	0.48	1.00
Rice (paddy)	0.43	0.43	1.00
Oilseeds	0.76	0.76	1.00
Pulses	0.55	0.55	1.00
Inputs			
Seed			
Irrigated wheat (own seed)	6.65	5.65	1.18
Nonirrigated wheat (own seed)	6.70	5.70	1.18
Rice (own seed)	6.21	5.28	1.18
Oilseeds (own seed)	19.66	16.71	1.18
Pulses (own seed)	18.88	16.04	1.18
Fertilizer			
Urea	5.96	5.96	1.00
Triple superphosphate (TSP)	7.61	8.72	0.87
Muriate of potash (MP)	6.78	7.98	0.85
Pesticide			
Irrigated wheat	n.a.	n.a.	. . .
Nonirrigated wheat	n.a.	n.a.	. . .
Boro rice	91.46	81.40	1.12
Diesel fuel (Tk/liter)	14.00	11.90	1.18
Labor		(Tk/day)	
Family labor			
Peak season	20.00	20.00	1.00
Slack season	20.00	10.00	2.00
Attached farm labor			
Peak season	26.04	26.04	1.00
Slack season	26.04	13.02	2.00
Casual labor			
Land preparation and broadcasting	37.47	37.47	1.00
Transplanting	35.97	35.97	1.00
Weeding	33.19	16.60	2.00
Harvesting and postharvest	38.99	38.99	1.00
All other activities	36.41	18.20	2.00

Sources: Financial prices collected through wheat producer survey. Economic prices calculated based on procedures explained in text.

Notes: Leaders (. . .) indicate a nil or negligible amount. N.a. indicates "not applicable."

Table 37—Comparison of selected financial and economic prices (SC Zone)

Item	Financial price	Economic price	Financial-economic price ratio
		(Tk/kilogram)	
Outputs			
Grain			
Irrigated wheat	5.09	8.10	0.63
Nonirrigated wheat	5.24	8.10	0.65
Rice (paddy)	5.59	5.59	1.00
Oilseeds	14.77	13.19	1.12
Pulses	16.45	15.11	1.09
By-products			
Irrigated wheat	0.35	0.35	1.00
Nonirrigated wheat	0.38	0.38	1.00
Rice (paddy)	0.32	0.32	1.00
Oilseeds	0.41	0.41	1.00
Pulses	0.57	0.57	1.00
Inputs			
Seed			
Irrigated wheat (own seed)	6.36	5.41	1.18
Nonirrigated wheat (own seed)	6.55	5.57	1.18
Rice (own seed)	5.86	4.98	1.18
Oilseeds (own seed)	18.46	15.69	1.18
Pulses (own seed)	20.56	17.48	1.18
Fertilizer			
Urea	6.06	6.06	1.00
Triple superphosphate (TSP)	8.19	8.78	0.93
Muriate of potash (MP)	6.76	8.04	0.84
Pesticide			
Irrigated wheat	n.a.	n.a.	. . .
Nonirrigated wheat	75.00	66.75	1.12
Boro rice	96.58	85.96	1.12
Diesel fuel (Tk/liter)	14.00	11.90	1.18
Labor		(Tk/day)	
Family labor			
Peak season	20.00	20.00	1.00
Slack season	20.00	10.00	2.00
Attached farm labor			
Peak season	26.59	26.59	1.00
Slack season	26.59	13.30	2.00
Casual labor			
Land preparation and broadcasting	38.49	38.49	1.00
Transplanting	35.61	35.61	1.00
Weeding	33.48	16.74	2.00
Harvesting and postharvest	36.88	36.88	1.00
All other activities	36.12	18.06	2.00

Sources: Financial prices collected through wheat producer survey. Economic prices calculated based on procedures explained in text.

Notes: Leaders (. . .) indicate a nil or negligible amount. N.a. indicates "not applicable."

Table 38—Comparison of selected financial and economic prices (SW Zone)

Item	Financial price	Economic price	Financial-economic price ratio
		(Tk/kilogram)	
Outputs			
Grain			
Irrigated wheat	5.24	8.34	0.63
Nonirrigated wheat	5.55	8.34	0.67
Rice (paddy)	6.31	6.31	1.00
Oilseeds	14.06	13.26	1.12
Pulses	16.05	15.16	1.06
By-products			
Irrigated wheat	0.41	0.41	1.00
Nonirrigated wheat	0.47	0.47	1.00
Rice (paddy)	0.40	0.40	1.00
Oilseeds	0.32	0.32	1.00
Pulses	0.58	0.58	1.00
Inputs			
Seed			
Irrigated wheat (own seed)	6.55	5.57	1.18
Nonirrigated wheat (own seed)	6.94	5.98	1.18
Rice (own seed)	6.63	5.63	1.18
Oilseeds (own seed)	17.58	14.94	1.18
Pulses (own seed)	20.06	17.05	1.18
Fertilizer			
Urea	5.96	5.96	1.00
Triple superphosphate (TSP)	7.77	8.71	0.89
Muriate of potash (MP)	6.83	7.97	0.86
Pesticide			
Irrigated wheat	n.a.	n.a.	. . .
Nonirrigated wheat	n.a.	n.a.	. . .
Boro rice	118.26	105.25	1.12
Diesel fuel (Tk/liter)	14.00	11.90	1.18
Labor		(Tk/day)	
Family labor			
Peak season	20.00	20.00	1.00
Slack season	20.00	10.00	2.00
Attached farm labor			
Peak season	31.04	31.02	1.00
Slack season	31.04	15.52	2.00
Casual labor			
Land preparation and broadcasting	34.78	34.78	1.00
Transplanting	34.73	34.73	1.00
Weeding	32.50	16.25	2.00
Harvesting and postharvest	39.09	39.09	1.00
All other activities	35.28	17.64	2.00

Sources: Financial prices collected through wheat producer survey. Economic prices calculated based on procedures explained in text.

Notes: Leaders (. . .) indicate a nil or negligible amount. N.a. indicates "not applicable."

Table 39—Comparison of selected financial and economic prices (NE Zone)

Item	Financial price	Economic price	Financial-economic price ratio
Outputs		(Tk/kilogram)	
Grain			
Irrigated wheat	n.a.	n.a.	. . .
Nonirrigated wheat	6.04	8.41	0.72
Rice (paddy)	5.69	5.69	1.00
Oilseeds	16.32	13.27	1.23
Pulses	n.a.	n.a.	. . .
By-products			
Irrigated wheat	n.a.	n.a.	. . .
Nonirrigated wheat	0.52	0.52	1.00
Rice (paddy)	0.37	0.37	1.00
Oilseeds	0.52	0.52	1.00
Pulses	n.a.	n.a.	. . .
Inputs			
Seed			
Irrigated wheat (own seed)	n.a.	n.a.	. . .
Nonirrigated wheat (own seed)	7.55	6.42	1.18
Rice (own seed)	5.98	5.08	1.18
Oilseeds (own seed)	20.40	17.34	1.18
Pulses (own seed)	n.a.	n.a.	. . .
Fertilizer			
Urea	5.89	5.89	1.00
Triple superphosphate (TSP)	8.05	8.81	0.89
Muriate of potash (MP)	6.94	8.07	0.86
Pesticide			
Irrigated wheat	n.a.	n.a.	. . .
Nonirrigated wheat	n.a.	n.a.	. . .
Boro rice	75.29	67.01	1.12
Diesel fuel (Tk/liter)	14.00	11.90	1.18
Labor		(Tk/day)	
Family labor			
Peak season	20.00	20.00	1.00
Slack season	20.00	10.00	2.00
Attached farm labor			
Peak season	43.65	43.65	1.00
Slack season	43.65	21.83	2.00
Casual labor			
Land preparation and broadcasting	36.43	36.43	1.00
Transplanting	35.48	35.48	1.00
Weeding	35.28	17.64	2.00
Harvesting and postharvest	50.40	50.40	1.00
All other activities	39.40	19.70	2.00

Sources: Financial prices collected through wheat producer survey. Economic prices calculated based on procedures explained in text.

Notes: Leaders (. . .) indicate a nil or negligible amount. N.a. indicates "not applicable."

Table 40—Financial profitability (NW Zone)

Costs	Irrigated		Nonirrigated		
	Wheat	*Boro* rice	Wheat	Oilseeds	Pulses
Grain yield (kilograms/hectare)	1,927	5,595	1,769	348	518
Gross revenues (Tk/hectare)	10,690	31,630	9,696	6,126	7,626
Fixed costs (Tk/hectare)					
Irrigation[a]	96	819	. . .	. . .	. . .
Animal traction[b]	675	666	1,068	608	819
Variable costs (Tk/hectare)					
Purchased inputs					
Seed	939	434	891	207	505
Urea	1,125	1,599	745	304	155
Triple superphosphate	961	951	633	407	71
Muriate of potash	384	358	228	196	28
Manure	732	607	651	538	560
Pesticide	56	348	92	0	0
Irrigation					
Repairs and maintenance	12	100	. . .	. . .	. . .
Fuel	371	3,172	. . .	. . .	. . .
Labor					
Family labor	759	1,000	1,344	695	933
Attached farm labor	223	448	76	147	355
Casual labor	1,933	4,032	1,486	797	1,270
Working capital	312	544	256	103	121
Total fixed costs (Tk/hectare)	771	1,485	1,068	608	819
Total variable costs (Tk/hectare)	7,808	13,593	6,403	3,392	3,997
Total costs (Tk/hectare)	8,578	15,078	7,472	4,001	4,816
Net returns (Tk/hectare)	2,111	16,552	2,224	2,125	2,810

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.
Note: Leaders (. . .) indicate a nil or negligible amount.
[a]Farmer-owned shallow tubewell powered by diesel fuel.
[b]Farmer-owned bullock team.

Table 41—Financial profitability (NC Zone)

Costs	Irrigated Wheat	Irrigated *Boro* rice	Nonirrigated Wheat	Nonirrigated Oilseeds	Nonirrigated Pulses
Grain yield (kilograms/hectare)	2,211	5,020	1,707	860	359
Gross revenues (Tk/hectare)	12,891	30,757	10,143	14,194	5,694
Fixed costs (Tk/hectare)					
Irrigation[a]	103	734	...	...	...
Animal traction[b]	1,086	527	814	411	283
Variable costs (Tk/hectare)					
Purchased inputs					
Seed	914	440	1,003	246	416
Urea	901	1,310	824	1,037	82
Triple superphosphate	758	428	361	1,120	86
Muriate of potash	166	154	65	521	4
Manure	346	62	61	10	18
Pesticide	0	123	0	0	0
Irrigation					
Repairs and maintenance	13	90	...	...	...
Fuel	398	2,841	...	...	...
Labor					
Family labor	1,353	1,163	1,045	381	454
Attached farm labor	421	290	100	99	52
Casual labor	2,683	4,972	704	371	226
Working capital	331	495	173	158	56
Total fixed costs (Tk/hectare)	1,189	1,261	814	411	283
Total variable costs (Tk/hectare)	8,284	12,368	4,336	3,944	1,394
Total costs (Tk/hectare)	9,473	13,629	5,150	4,355	1,676
Net returns (Tk/hectare)	3,418	17,128	4,993	9,839	4,017

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.
Note: Leaders (. . .) indicate a nil or negligible amount.
[a]Farmer-owned shallow tubewell powered by diesel fuel.
[b]Farmer-owned bullock team.

Table 42—Financial profitability (SC Zone)

Costs	Irrigated		Nonirrigated		
	Wheat	*Boro* rice	Wheat	Oilseeds	Pulses
Grain yield (kilograms/hectare)	2,651	4,579	1,393	324	563
Gross revenues (Tk/hectare)	14,188	26,427	7,902	4,986	9,683
Fixed costs (Tk/hectare)					
Irrigation[a]	193	850	...	...	...
Animal traction[b]	631	580	657	353	610
Variable costs (Tk/hectare)					
Purchased inputs					
Seed	958	527	930	122	794
Urea	1,496	1,310	357	113	58
Triple superphosphate	1,026	1,066	907	187	208
Muriate of potash	353	304	150	13	38
Manure	277	126	30	73	200
Pesticide	0	404	54	0	0
Irrigation					
Repairs and maintenance	24	104	...	...	...
Fuel	747	3,293	...	...	...
Labor					
Family labor	567	1,170	900	398	529
Attached farm labor	169	144	16	53	87
Casual labor	2,867	6,365	545	307	541
Working capital	353	617	162	40	77
Total fixed costs (Tk/hectare)	824	1,431	657	353	610
Total variable costs (Tk/hectare)	8,835	15,431	4,050	1,306	2,531
Total costs (Tk/hectare)	9,659	16,861	4,707	1,659	3,142
Net returns (Tk/hectare)	4,529	9,566	3,195	3,327	6,541

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.
Note: Leaders (. . .) indicate a nil or negligible amount.
[a]Farmer-owned shallow tubewell powered by diesel fuel.
[b]Farmer-owned bullock team.

Table 43—Financial profitability (SW Zone)

Costs	Irrigated		Nonirrigated		
	Wheat	*Boro* rice	Wheat	Oilseeds	Pulses
Grain yield (kilograms/hectare)	1,846	4,438	1,581	721	680
Gross revenues (Tk/hectare)	10,379	28,748	9,615	10,370	11,323
Fixed costs (Tk/hectare)					
Irrigation[a]	67	695	...	...	...
Animal traction[b]	369	488	699	411	703
Variable costs (Tk/hectare)					
Purchased inputs					
Seed	3,089	531	1,516	273	850
Urea	966	1,396	687	773	131
Triple superphosphate	631	877	730	840	153
Muriate of potash	200	257	170	85	13
Manure	132	204	107	28	0
Pesticide	0	529	0	110	0
Irrigation					
Repairs and maintenance	8	85	...	...	...
Fuel	261	2,692	...	...	...
Labor					
Family labor	711	1,408	1,225	652	854
Attached farm labor	77	120	11	55	56
Casual labor	1,842	5,246	655	377	658
Working capital	330	556	213	133	113
Total fixed costs (Tk/hectare)	436	1,183	699	411	703
Total variable costs (Tk/hectare)	8,247	13,901	5,312	3,328	2,828
Total costs (Tk/hectare)	8,683	15,083	6,011	3,739	3,530
Net returns (Tk/hectare)	1,696	13,664	3,604	6,631	7,792

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.
Note: Leaders (. . .) indicate a nil or negligible amount.
[a]Farmer-owned shallow tubewell powered by diesel fuel.
[b]Farmer-owned bullock team.

Table 44—Financial profitability (NE Zone)

Costs	Irrigated		Nonirrigated		
	Wheat	*Boro* rice	Wheat	Oilseeds	Pulses
Grain yield (kilograms/hectare)	...	2,176	1,636	1,430	...
Gross revenues (Tk/hectare)	...	12,807	10,690	23,930	...
Fixed costs (Tk/hectare)					
Irrigation[a]	...	0	...	...	...
Animal traction[b]	...	368	861	562	...
Variable costs (Tk/hectare)					
Purchased inputs					
Seed	...	348	2,161	900	...
Urea	...	1,083	1,249	1,036	...
Triple superphosphate	...	392	1,316	1,349	...
Muriate of potash	...	56	96	494	...
Manure	...	0	0	0	...
Pesticide	...	116	0	0	...
Irrigation					
Repairs and maintenance	...	0	...	...	...
Fuel	...	0	...	...	...
Labor					
Family labor	...	1,083	837	299	...
Attached farm labor	...	1,374	350	335	...
Casual labor	...	4,114	1,664	812	...
Working capital	...	357	320	163	...
Total fixed costs (Tk/hectare)	...	368	861	562	...
Total variable costs (Tk/hectare)	...	8,924	7,994	5,388	...
Total costs (Tk/hectare)	...	9,292	8,855	5,951	...
Net returns (Tk/hectare)	...	3,515	1,835	17,979	...

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.
Note: Leaders (. . .) indicate a nil or negligible amount.
[a]Farmer-owned shallow tubewell powered by diesel fuel.
[b]Farmer-owned bullock team.

Table 45—Economic profitability (NW Zone)

	Irrigated		Nonirrigated		
Costs	Wheat	*Boro* rice[a]	Wheat	Oilseeds	Pulses
Grain yield (kilograms/hectare)	1,927	5,595	1,769	348	518
Gross revenues (Tk/hectare)	16,872	31,630	15,303	5,109	8,233
Fixed costs (Tk/hectare)					
Irrigation[b]	85	729	. . .	. . .	. . .
Animal traction[c]	675	666	1,068	608	819
Variable costs (Tk/hectare)					
Purchased inputs					
Seed	798	369	757	176	430
Urea	1,125	1,599	745	304	155
Triple superphosphate	1,066	1,055	703	452	78
Muriate of potash	481	449	285	246	35
Manure	732	607	651	538	560
Pesticide	50	310	82	0	0
Irrigation					
Repairs and maintenance	8	70	. . .	. . .	. . .
Fuel	316	2,696	. . .	. . .	. . .
Labor					
Family labor	689	817	1,299	695	822
Attached farm labor	212	357	73	147	296
Casual labor	1,879	3,740	1,474	797	1,065
Working capital	306	503	253	105	107
Total fixed costs (Tk/hectare)	760	1,395	1,068	608	819
Total variable costs (Tk/hectare)	7,662	12,571	6,323	3,457	3,547
Total costs (Tk/hectare)	8,422	13,966	7,392	4,066	4,366
Net returns (Tk/hectare)	8,450	17,664	7,911	1,043	3,866

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.
Note: Leaders (. . .) indicate a nil or negligible amount.
[a]Baseline scenario in which Bangladesh is assumed to be self-sufficient in rice.
[b]Farmer-owned shallow tubewell powered by diesel fuel.
[c]Farmer-owned bullock team.

Table 46—Economic profitability (NC Zone)

Costs	Irrigated		Nonirrigated		
	Wheat	*Boro* rice[a]	Wheat	Oilseeds	Pulses
Grain yield (kilograms/hectare)	2,211	5,020	1,707	860	359
Gross revenues (Tk/hectare)	19,153	30,757	14,910	12,062	5,713
Fixed costs (Tk/hectare)					
Irrigation[b]	91	653	. . .	. . .	. . .
Animal traction[c]	1,086	527	814	411	283
Variable costs (Tk/hectare)					
Purchased inputs					
Seed	777	374	852	209	354
Urea	901	1,310	824	1,037	82
Triple superphosphate	869	490	413	1,283	98
Muriate of potash	195	181	77	613	5
Manure	346	62	61	10	18
Pesticide	0	0	0	0	0
Irrigation					
Repairs and maintenance	11	80	. . .	. . .	. . .
Fuel	338	2,415	. . .	. . .	. . .
Labor					
Family labor	1,211	963	1,022	381	454
Attached farm labor	412	260	99	98	51
Casual labor	2,463	4,544	634	328	211
Working capital	313	445	166	165	53
Total fixed costs (Tk/hectare)	1,177	1,180	814	411	283
Total variable costs (Tk/hectare)	7,835	11,123	4,147	4,124	1,325
Total costs (Tk/hectare)	9,013	12,303	4,962	4,535	1,608
Net returns (Tk/hectare)	10,141	18,453	9,948	7,527	4,105

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.
Note: Leaders (. . .) indicate a nil or negligible amount.
[a]Baseline scenario in which Bangladesh is assumed to be self-sufficient in rice.
[b]Farmer-owned shallow tubewell powered by diesel fuel.
[c]Farmer-owned bullock team.

Table 47—Economic profitability (SC Zone)

Costs	Irrigated		Nonirrigated		
	Wheat	*Boro* rice[a]	Wheat	Oilseeds	Pulses
Grain yield (kilograms/hectare)	2,651	4,579	1,393	324	563
Gross revenues (Tk/hectare)	22,174	26,427	11,891	4,475	8,926
Fixed costs (Tk/hectare)					
Irrigation[b]	172	757	...	...	...
Animal traction[c]	631	580	657	353	610
Variable costs (Tk/hectare)					
Purchased inputs					
Seed	814	448	790	103	675
Urea	1,496	1,310	357	113	58
Triple superphosphate	1,099	1,143	972	200	223
Muriate of potash	419	361	178	16	45
Manure	277	126	30	73	200
Pesticide	0	359	48	0	0
Irrigation					
Repairs and maintenance	16	72	...	...	...
Fuel	635	2,799	...	...	...
Labor					
Family labor	536	962	900	398	517
Attached farm labor	168	139	16	52	87
Casual labor	2,830	5,589	500	276	482
Working capital	345	555	158	38	71
Total fixed costs (Tk/hectare)	803	1,337	657	353	610
Total variable costs (Tk/hectare)	8,636	13,863	3,949	1,270	2,358
Total costs (Tk/hectare)	9,438	15,200	4,606	1,623	2,968
Net returns (Tk/hectare)	12,736	11,227	7,285	2,852	5,958

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.
Note: Leaders (. . .) indicate a nil or negligible amount.
[a]Baseline scenario in which Bangladesh is assumed to be self-sufficient in rice.
[b]Farmer-owned shallow tubewell powered by diesel fuel.
[c]Farmer-owned bullock team.

Table 48—Economic profitability (SW Zone)

Costs	Irrigated		Nonirrigated		
	Wheat	*Boro* rice[a]	Wheat	Oilseeds	Pulses
Grain yield (kilograms/hectare)	1,846	4,438	1,581	721	680
Gross revenues (Tk/hectare)	16,099	28,748	14,022	9,794	10,717
Fixed costs (Tk/hectare)					
Irrigation[b]	60	619	. . .	. . .	. . .
Animal traction[c]	369	488	699	411	703
Variable costs (Tk/hectare)					
Purchased inputs					
Seed	2,625	451	1,288	232	722
Urea	966	1,396	687	773	131
Triple superphosphate	707	983	818	942	172
Muriate of potash	234	300	198	99	15
Manure	132	204	107	28	0
Pesticide	0	470	0	98	0
Irrigation					
Repairs and maintenance	6	59	. . .	. . .	. . .
Fuel	222	2,288	. . .	. . .	. . .
Labor					
Family labor	699	1,161	1,122	645	830
Attached farm labor	77	99	11	55	56
Casual labor	1,797	4,710	569	331	572
Working capital	311	505	200	133	104
Total fixed costs (Tk/hectare)	428	1,106	699	411	703
Total variable costs (Tk/hectare)	7,775	12,627	5,001	3,336	2,602
Total costs (Tk/hectare)	8,204	13,733	5,700	3,748	3,305
Net returns (Tk/hectare)	7,895	15,015	8,322	6,046	7,412

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.
Note: Leaders (. . .) indicate a nil or negligible amount.
[a]Baseline scenario in which Bangladesh is assumed to be self-sufficient in rice.
[b]Farmer-owned shallow tubewell powered by diesel fuel.
[c]Farmer-owned bullock team.

Table 49—Economic profitability (NE Zone)

Costs	Irrigated		Nonirrigated		
	Wheat	*Boro* rice[a]	Wheat	Oilseeds	Pulses
Grain yield (kilograms/hectare)	. . .	2,176	1,636	1,430	. . .
Gross revenues (Tk/hectare)	. . .	12,807	14,575	19,562	. . .
Fixed costs (Tk/hectare)					
Irrigation[b]	. . .	0	. . .	. . .	. . .
Animal traction[c]	. . .	368	861	562	. . .
Variable costs (Tk/hectare)					
Purchased inputs					
Seed	. . .	296	1,159	765	. . .
Urea	. . .	1,083	1,249	1,036	. . .
Triple superphosphate	. . .	429	1,440	1,476	. . .
Muriate of potash	. . .	65	112	575	. . .
Manure	. . .	0	0	0	. . .
Pesticide	. . .	103	0	0	. . .
Irrigation					
Repairs and maintenance	. . .	0	. . .	. . .	. . .
Fuel	. . .	0	. . .	. . .	. . .
Labor					
Family labor	. . .	797	831	299	. . .
Attached farm labor	. . .	1,059	349	330	. . .
Casual labor	. . .	3,701	1,664	812	. . .
Working capital	. . .	314	284	165	. . .
Total fixed costs (Tk/hectare)	. . .	368	861	562	. . .
Total variable costs (Tk/hectare)	. . .	7,847	7,088	5,458	. . .
Total costs (Tk/hectare)	. . .	8,215	7,949	6,020	. . .
Net returns (Tk/hectare)	. . .	4,591	6,625	13,542	. . .

Source: Calculated by the authors based on data from the CIMMYT-IFPRI producer survey, 1993.
Note: Leaders (. . .) indicate a nil or negligible amount.
[a]Baseline scenario in which Bangladesh is assumed to be self-sufficient in rice.
[b]Farmer-owned shallow tubewell powered by diesel fuel.
[c]Farmer-owned bullock team.

References

Abdul Aziz, M. 1993. Production and consumption of wheat in Bangladesh. Canadian High Commission, Dhaka. Photocopy.

Ahmed, A. U. 1993. *Food consumption and nutritional effects of targeted food interventions in Bangladesh.* Bangladesh Food Policy Project Working Paper 31. Dhaka: International Food Policy Research Institute.

Ahmed, A. U., D. Puetz, S. Zohir, and N. Hassan. 1996. Joint evaluation of European Union Programme Food Aid Stage Two. Bangladesh: An extended study. Revised report prepared for the European Development Council Working Group of Heads of Evaluation. International Food Policy Research Institute. Washington, D.C. Photocopy.

Ahmed, R. 1979. *Foodgrain supply, distribution, and consumption policies within a dual pricing mechanism: A case study of Bangladesh.* Research Report 8. Washington, D.C.: International Food Policy Research Institute.

———. 1988. Pricing principles and public interventions in domestic markets. In *agricultural price policy for developing countries,* ed. J. Mellor and R. Ahmed. Baltimore and London: Johns Hopkins University Press for the International Food Policy Research Institute.

Ahmed, S. M. 1992. A survey of Bangladesh wheat area and production for 1992/93. International Maize and Wheat Improvement Center, Dhaka. Photocopy.

Bangladesh Bureau of Statistics. Various issues. *Statistical yearbook of Bangladesh.* Dhaka: BBS.

Bangladesh, Master Plan Organization. 1986. *National water plan,* vol. 1. Dhaka: MPO.

Bruno, M. 1967. The optimal selection of export-promoting and import-substituting projects. *Planning the external sector: Techniques, problems, and policies*. Report on the First Interregional Seminar on Development Planning, Ankara, Turkey, 6–17 September, 1965, Document ST/TAO/SER.c/91: 88–135. New York: United Nations.

Byerlee, D. 1985. *Comparative advantage and policy incentives for wheat production in Ecuador*. Economics Program Working Paper 01/85. Mexico, D.F.: International Maize and Wheat Improvement Center.

———. 1994. *Modern varieties, productivity, and sustainability: Recent experiences and emerging challenges*. Technical Bulletin. Mexico, D.F.: International Maize and Wheat Improvement Center.

Byerlee, D., and J. Longmire. 1986. *Comparative advantage and policy incentives for rainfed and irrigated wheat in Mexico*. Economics Program Working Paper 01/86. Mexico, D.F.: International Maize and Wheat Improvement Center.

Byerlee, D., and M. L. Morris. 1993. Calculating levels of protection: Is it always appropriate to use world reference prices based on current trading patterns? *World Development* 21 (no.5): 805–815.

Chowdhury, N. 1988. Where the poor come last: The case of modified rationing in Bangladesh. *The Bangladesh Development Studies* 16: 27–51.

———. 1991. *Optimal stock for the public foodgrain distribution system in Bangladesh.* Bangladesh Food Policy Project Working Paper 4. Dhaka: International Food Policy Research Institute.

———. 1992a. Rice price environment and extreme poverty in Bangladesh: A comparison between 1970s and 1980s. In *Coping with disaster: The case of Bangladesh*, ed. C. Dodge, H. Hossain, and F. H. Abed. Dhaka: The University Press.

———. 1992b. Rice markets in Bangladesh: A study in structure, conduct and performance. Bangladesh Food Policy Project, Dhaka. Photocopy.

———. 1993a. Interactions between private rice stocks and public stock policy in Bangladesh: Evidence for a crowding out. Bangladesh Food Policy Project, Dhaka. Photocopy.

———. 1993b. The structure and conduct of Bangladesh's wheat markets: Some emerging insights. Bangladesh Food Policy Project, Dhaka. Photocopy.

———. 1993c. A study of rice grades in Bangladesh. Bangladesh Food Policy Project, Dhaka. Photocopy.

———. 1994a. Causalities and cost effectiveness of public rice procurement in Bangladesh. Paper presented to the Seminar on Emerging Food Markets and Food Policy, jointly sponsored by the Government of Bangladesh, the International Food Policy Research Institute and the U. S. Agency for International Development, Dhaka, May 2–4.

———. 1994b. Credit and Bangladesh's foodgrain market: New evidence on commercialization, credit relations, and effect of credit access. Bangladesh Food Policy Project, Dhaka. Photocopy.

Chowdhury, N., and N. Farid. 1994. Access to non-cereal food and household food security: Concepts, evidence, and implications for food policy. Paper presented to the Seminar on Emerging Food Markets and Food Policy, jointly sponsored by the Government of Bangladesh, International Food Policy Research Institute, and the U. S. Agency for International Development, Dhaka, May 2–4.

CIMMYT (International Maize and Wheat Improvement Center). 1991. *1990–91 CIMMYT world wheat facts and trends: Wheat and barley production in rainfed marginal environments of the developing world.* Mexico, D.F.: CIMMYT.

Dorosh, P., and S. Haggblade. 1996. Shifting sands: The changing case for monetizing project food aid in Bangladesh. Cornell Food and Nutrition Policy Program, Ithaca, N.Y. Photocopy.

FAO (Food and Agriculture Organization of the United Nations). 1995. FAO Agrostat-PC, V.3.0. Crop production domain. Rome. Computer disk.

Goletti, F. 1994. *The changing public role in a rice economy approaching self-sufficiency: The case of Bangladesh.* Research Report 98. Washington, D.C.: International Food Policy Research Institute.

Gotsch, C., and Brown, G. 1980. *Prices, taxes, and subsidies in Pakistan agriculture, 1960–1976.* World Bank Staff Working Paper. Washington, D.C.: World Bank.

Greene, W. 1993. *Econometric analysis,* 2nd ed. New York: MacMillan.

Guisselquist, D. 1992. Empowering farmers in Bangladesh: Trade reforms open door to new technology. Paper presented at the Annual Conference of the Association for Economic Development Studies on Bangladesh, November 21–22, World Bank, Washington, D.C.

Haggblade, S. 1994. Emerging foodgrain markets and food policy. Keynote paper for the Seminar on Emerging Food Markets and Food Policy, jointly sponsored by the Government of Bangladesh, International Food Policy Research Institute, and U.S. Agency for International Development. Dhaka, May 2–4.

Haggblade, S., and M. Rahman. 1993. The laws of gravity: A review of rice price movements during the boro season of 1992. Bangladesh Food Policy Project, Dhaka. Photocopy.

Hassan, R. M., and H. Faki. 1993. *Economic policy and technology determinants of the comparative advantage of wheat production in Sudan.* Economics Paper 6. Bangkok, Thailand: International Maize and Wheat Improvement Center.

Hossain, M. 1987. Fertilizer consumption, pricing, and foodgrain production in Bangladesh. In *Fertilizer pricing policy in Bangladesh,* ed. B. Stone. Dhaka: International Food Policy Research Institute and Bangladesh Institute of Development Studies.

Jackson, G. J. 1992. *Agrochemical usage in Asia Region.* Washington D.C.: World Bank.

Krueger, A. O. 1966. Some economic costs of exchange control: The Turkish case. *Journal of Political Economy* 74: 466–480.

Little, I., and J. Mirrlees. 1974. *Project appraisal and planning for developing countries.* London: Heinemann.

Longmire, J., and J. Lugogo. 1990. *The economics of small-scale wheat production technologies for Kenya.* Economics Program Working Paper 89/01. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT).

Mahmud, W., S. H. Rahman, and S. Zohir. 1994. *Agricultural growth through crop diversification in Bangladesh.* Working Papers on Food Policy in Bangladesh 7. Washington, D.C.: International Food Policy Research Institute.

Marten, R. 1993. Final report: Alternative commodity system. Report prepared for the U.S. Agency for International Development, Dhaka. Photocopy.

Masters, W., and A. Winter-Nelson. 1995. Measuring the comparative advantage of agricultural activities: Domestic resource costs and the social cost-benefit ratio. *American Journal of Agricultural Economics* 77 (no. 2): 243–250.

Monke, E. A., and S. R. Pearson. 1989. *The policy analysis matrix for agricultural development.* Ithaca and London: Cornell University Press.

Morris, M. L. 1989. *Determining comparative advantage through DRC analysis: Guidelines emerging from CIMMYT's experience.* Economics Paper 1. Mexico, D.F.: International Maize and Wheat Improvement Center.

Mott MacDonald International, Ltd. 1990. *Deep Tubewell II Project: Main report.* Report prepared for the Overseas Development Agency. Dhaka.

Osman, S. R., and M. A. Quasam. 1990. *Pricing and subsidy policy for Bangladesh agriculture.* Research Monograph 11. Dhaka: Bangladesh Institute of Development Studies.

Rab, A. 1984. Shadow wages of urban and rural unskilled labor in Bangladesh: A preliminary set of estimates. Trade and Industry Reform Project, Dhaka. Photocopy.

Rahman, S. H. 1994. *The impact of trade and exchange rate policies on economic incentives in Bangladesh agriculture.* Working Papers on Food Policy in Bangladesh 8. Washington, D.C.: International Food Policy Research Institute.

Ravallion, M. 1987. *Markets and famine.* Oxford: Clarendon Press.

Scandizzo, P. L. and C. Bruce. 1980. *Methodologies for measuring agricultural price interventions effects.* World Bank Staff Working Paper No. 394. Washington, D.C.: World Bank.

Sen, A. K. 1981. *Poverty and famines.* Oxford: Oxford University Press.

Shahabuddin, Q., and K. M. Rahman. 1992. *Estimation of economic prices of selected commodities for use in flood action plan studies.* Dhaka: Water Development Board.

Singh, I. 1988. *Land and labor in South Asia.* World Bank Discussion Paper 33. Washington, D.C.: World Bank.

Srinivasan, T. N., and J. N. Bhagwati, 1978. Shadow prices for project selection in the presence of distortions: Effective rates of protection and domestic resource costs. *Journal of Political Economy* 86: 97–116.

Tsakok, I. 1990. *Agricultural price policy: A practitioner's guide to partial equilibrium analysis.* Ithaca, N.Y.: Cornell University Press.

Uddin, T., R. K. Talukder, and M. S. Alam. 1994. Optimum cropping plan for a sample of farms in a farming system research area of Bangladesh. *Bangladesh Journal of Agricultural Economics* 27 (nos. 1 and 2): 85–96.

Uniconsult. 1992. Study of seed, feed, and wastage in foodgrains. Dhaka. Photocopy.

Wennergren, E. B., C. H. Anhalt, and M. D. Whitaker. 1984. *Agricultural development in Bangladesh.* Boulder, Colo., U.S.A.: Westview Press.

World Bank. 1992. *Bangladesh: Food policy review. Adjusting to the Green Revolution.* Washington, D.C.: World Bank.

———. 1993a. *Bangladesh: Agricultural strategy paper.* Washington, D.C.: World Bank.

———. 1993b. *Bangladesh: Implementing structural reform.* Washington, D.C.: World Bank.

———. 1995. *World development report: 1995.* Washington, D.C.: World Bank.

Michael L. Morris is a senior scientist with the Economics Program of the International Maize and Wheat Improvement Center (CIMMYT) and is based in Mexico. He was a visiting researcher at the International Food Policy Research Institute (IFPRI) from September 1995 to August 1996. At the time this study was conducted, Nuimuddin Chowdhury was based in Dhaka with the Bangladesh Food Policy Project of IFPRI. Craig Meisner is a scientist with the Wheat Program of CIMMYT and is based in Dhaka.

Recent IFPRI Research Reports (continued)

91 *Rural Infrastructure, the Settlement System, and Development of the Regional Economy in Southern India*, by Sudhir Wanmali, 1992

90 *Labor in the Rural Household Economy of the Zairian Basin*, by Tshikala B. Tshibaka, 1992

89 *Growth in Japan's Horticultural Trade with Developing Countries: An Economic Analysis of the Market*, by Masayoshi Honma, 1991

88 *Drought and Famine Relationships in Sudan: Policy Implications*, by Tesfaye Teklu, Joachim von Braun, and Elsayed Zaki, 1991

87 *Incentives and Constraints in the Transformation of Punjab Agriculture*, by Anya McGuirk and Yair Mundlak, 1991

86 *The Effects of International Remittances on Poverty, Inequality, and Development in Rural Egypt*, by Richard Adams, Jr., 1991

85 *Commercialization of Agriculture Under Population Pressure: Effects on Production, Consumption, and Nutrition in Rwanda*, by Joachim von Braun, Hartwig de Haen, and Juergen Blanken, 1991

IFPRI Research Reports
Publications Review Committee and Procedures

Lawrence Haddad, Chair

Suresh Babu

Mylène Kherallah

Hans Löfgren

Ruth Meinzen-Dick

Philip Pardey

Agnes Quisumbing

Phyllis Skillman (ex officio)

ll manuscripts submitted for publication as IFPRI Research Reports undergo extensive review. Prior to submission to the Publications Review Committee, each manuscript is circulated informally among the author's colleagues, presented in a formal seminar, and reviewed by an IFPRI reviewer. Following submission of the manuscript to the Committee, three additional reviewers—at least two external to IFPRI and one from the Committee—are selected to review the manuscript. Reviewers are chosen for their expertise in the manuscript's subject matter and methodology and, when applicable, their familiarity with the country setting. The Committee provides the author its reaction to the reviewers' comments. After revising as necessary, the author resubmits the manuscript to the Committee with a written response to the reviewers' and Committee's comments. The Committee then makes its recommendations on publication of the manuscript to the Director General of IFPRI. With the Director General's approval, the manuscript becomes part of the IFPRI Research Report series.

Recent IFPRI Research Reports

105 *Groundwater Markets in Pakistan: Participation and Productivity,* by Ruth Meinzen-Dick, 1996

104 *Role of Farm-Level Diversification in the Adoption of Modern Technology in Brazil,* by Marc Nerlove, Stephen Vosti, and Wesley Basel, 1996

103 *Regional Trading Arrangements among Developing Countries: The ASEAN Example,* by Dean A. DeRosa, 1995

102 *Sources of Income Inequality and Poverty in Rural Pakistan,* by Richard H. Adams, Jr. and Jane J. He, 1995

101 *Pricing Behavior in Philippine Corn Markets: Implications for Market Efficiency,* by Meyra Sebello Mendoza and Mark W. Rosegrant, 1995

100 *Adoption of Hybrid Maize in Zambia: Effects on Gender Roles, Food Consumption, and Nutrition,* by Shubh K. Kumar, 1994

99 *Economic Reform in Europe and the Former Soviet Union: Implications for International Food Markets,* by Rod Tyers, 1994

98 *The Changing Public Role in a Rice Economy Approaching Self-Sufficiency: The Case of Bangladesh,* by Francesco Goletti, 1994

97 *Trade Pessimism and Regionalism in African Countries: The Case of Groundnut Exporters,* by Ousmane Badiane and Sambouh Kinteh, 1994

96 *Poverty, Household Food Security, and Nutrition in Rural Pakistan,* by Harold Alderman and Marito Garcia, 1993

95 *Sectoral Growth in Chile: 1962–82,* by Juan Eduardo Coeymans and Yair Mundlak, 1993

94 *Fertilizer Use on Smallholder Farms in Eastern Province, Zambia,* by Dayanatha Jha and Behjat Hojjati, 1993

93 *Economic Incentives and Comparative Advantage in Indonesian Food Crop Production,* by Leonardo A. Gonzales, Faisal Kasryno, Nicostrato D. Perez, and Mark W. Rosegrant, 1993

92 *Famine in Ethiopia: Policy Implications of Coping Failure at National and Household Levels,* by Patrick Webb, Joachim von Braun, and Yisehac Yohannes, 1992

(continued on inside back cover)

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
1200 SEVENTEENTH STREET, N.W., WASHINGTON, D.C. 20036-3006 U.S.A.
PHONE: 1-202-862-5600 • FAX: 1-202-467-4439
E-MAIL: ifpri@cgnet.com • WEB: www.cgiar.org/ifpri